



PHD

Fitness for the future: applying biomimetics to business strategy

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Fitness for the future: applying biomimetics to business strategy

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A thesis submitted for the degree of Doctor of Philosophy

University of Bath

Department of Mechanical Engineering

March 2010

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Abstract

Biomimetics has traditionally meant the study of the structure and function of biological systems as models for the design and engineering of materials and machines. Some stunning results showing how biomimetics has been put into practice include Velcro, the Millennium Dome in London and the Millennium Bridge in spanning the River Tyne in Newcastle.

Business biomimetics is a new term developed as part of this thesis and is proposed as an emerging field within biomimetics. It is distinct from the current use of biomimetics in that it demonstrates a strategic use in the business environment. This thesis examines how biomimetics can be used to aid business and tests whether businesses can improve their fitness for the future by applying the principles of biomimetics to the development of business strategy.

Research groups at the University of Bath were used as the basis of testing this hypothesis, fitness for the future. Results were measured by comparing conventional management models with newly developed business biomimetic models. Analysis of the results demonstrated evidence to support the hypothesis that business biomimetics had a positive effect on the future fitness for the groups as measured by increases in values for esteem and the generation of intellectual capital. These are nationally recognised measures for the success of research groups. Further evidence was gathered from a number of case studies that span a range of industries and disciplines. These case studies show that results are encouraging and the ideas generated by the business biomimetic models demonstrate a richer set of ideas that inspire the managers involved. One case follows the business from previous failure through the development of business biomimetically inspired ideas, implementation and into measureable results. Subsequent improvements include increased revenue, reduced costs, improved supply chain efficiency, better customer relationships and a clearer understanding of the cross functional integration value.

The delivery of a business biomimetic approach was facilitated by my invention of the Infinity Context Free Process that provided a framework to translate business problems into biological research areas and then the formulation of implementable business projects. A glimpse into the future for business biomimetics is provided in Chapter 9 that presents examples of the application of business biomimetics and shares the embryonic first steps by businesses to use nature as a guiding principle in sustainability, corporate social responsibility, growth and leadership development. The use of business biomimetics opens up the 3.8 billion years worth of nature's expertise and provides a new way for business leaders to innovate. The thesis concludes that when coupled with conventional management approaches, it further provides a way to design and manage businesses that are fit for now and for the future.

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Table of contents

Contents

Abstract	2
Acknowledgements.....	3
Table of contents	4
Figures	10
Tables	12
Chapter 1 Introduction.....	15
Objectives.....	15
Background	15
What is biomimetics?.....	19
Biomimcry	21
Chapter 2 Management science	22
Current thinking in management.....	22
The strategy process	23
Conventional wisdom.....	29
The search for something new.....	29
Identifying the business issues.....	30
Selected business models	32
Porter's five forces (Porter 1980)	32
A resource based approach to strategy analysis (Grant 2006)	33
A general model of the value chain	33
Key success factors	34
Selecting the strategy models.....	34
Management and biology	35
Management Systems	35

The death of competition	36
The wider application of biology in business.....	37
Summary of biology in management	38
Chapter 3 How biology might have the answer.....	39
MRS GREN	41
Movement	41
Respiration	43
Sensitivity.....	43
Growth	44
Reproduction	45
Excretion	46
Nutrition.....	47
Interrelationships	48
Evolution	51
Glue.....	53
How nature operates	54
Biomimetics – examples	55
Design.....	55
Biology and Engineering	55
Technology.....	57
Robots.....	58
Structure	59
Lotus effect	59
Microfluidics	60
The man machine interface	61
Linking Biology and engineering	61
Architectural examples	62
Getting to the hypothesis	64
Chapter 4 Building the biomimetic models	66

Biomimetic models	66
The biological systems and the reasons why they were chosen.....	68
Building the models	71
Flocking	71
Symbiosis	73
Poison Adaptor	75
Alternation of generations	76
Two hosted parasites.....	78
Past casting	79
MRS GREN.....	80
Life stages in two environments.....	81
Chapter 5 Testing the biomimetic models.....	84
Standard experimental approach	84
Experimental design and validity	84
Aim – define the aim of the experiment	85
Materials – define the businesses and therefore people involved	85
KPI’s – set the measures	86
Materials – set the variables to be tested	87
Test case results	93
Headings per KPI	95
Ideas generated by model	96
Correlation analysis	97
Group A (Biomimetic)	99
Group B (Business).....	106
Group C (Control).....	111
Test case discussion	115
General observations.....	117
Chapter 6 The application of biomimetic models in industry using case studies	119
Case study method.....	119
Military Policy Group	120

Health Insurance	121
File storage.....	123
Weapons supplier	128
Food & Beverage.....	129
Brewery.....	130
Case studies Results	137
Use of the models in the case studies	137
Summary of the results.....	138
Chapter 7 Inventing the Infinity Context Free Process	140
Taking particular technique and applying to a new area	140
The development of a business biomimetic process: the Infinity context-free process model	140
The working of the Infinity Context Free Process Model	141
Chapter 8 Further developments in Biomimetics.....	145
Opportunities to share the business biomimetic ideas	145
Biomimetics, the models, business and the environment	145
On the Origin of Business.....	146
Lamarckism for management	148
Natural intelligence	149
Transformation – the struggle for existence	150
The future of the business biomimetic models	151
Creating models of the future.....	151
The application of business biomimetics to business; new cases	156
Consumer packaged goods.....	156
MoD Procurement	157
IT	158
International IT consultancy	160
Summary of the model use	162

Chapter 9 Experience with the application of business biomimetics.....	164
The application of business biomimetics	164
The people involved.....	164
The simplicity of complex biological systems	165
Business biomimetics accessibility.....	167
Sustainability using biomimetics.....	167
The future for business biomimetics	167
What this tells us about creating the business biomimetic models of the future	169
Competitors to the business biomimetic approach.....	169
Determining the appropriate Key Performance Indicators	170
TRIZ and complex problem solving	171
Change management	175
Business biomimetics and design and innovation	177
Consulting	179
Customers	179
Mass collaboration as a way of biologizing business	180
Problems with Problem definition.....	180
Making another chicken.....	181
Chapter 10 Conclusion	183
Introduction	183
Background theory.....	184
Focal theory.....	186
The original business problem.....	186
Business biomimetics generates ideas	188
Depth of Biology understanding	190
Data theory	191
Evaluating the impact of the thesis.....	193

The importance of people in business.....	193
Further developing the business biomimetic models	195
The contribution to strategic thinking.....	196
Management science.....	197
Innovation replaces costs as the driver for strategy	197
Biomimetic hierarchy.....	198
Fit for the future	198
Limitation of the method used	200
Meeting the objectives	200
Further work	200
References.....	202
Appendix A: Test case results, detail	210
Group A (Biomimetic)	210
Group B (Business).....	213
Group C (Control).....	217
Appendix B: Open University Business Strategy Models.....	220
Appendix C: Symbiosis future systems for analysis	222
Appendix D: Definition of ecosystem.....	226
Appendix E: PhD process.....	229
Appendix F: Technology mission and Biokon.....	230

Figures

Figure 1: The strategy process after Johnson & Scholes 1993	24
Figure 2: Scope of management science	30
Figure 3 Strategy Model based on Porter's 5 Forces 1980 showing the forces that shape an industry.....	32
Figure 4 A Resource based approach to strategy based on Grant 2006.	33
Figure 5 A general model of a value chain after Porter 1985. The model is drawn as an arrow because it shows the flow of value towards the customer and profitability.	33
Figure 6 Identifying Key Success Factors after Grant 1995.	34
Figure 7: the two models of parasitism	50
Figure 8: alarm signals, the release of volatile organic compounds (VOCs) to attract herbivore predators after (Halitschke, Stenberg et al. 2008).....	51
Figure 9: different types of glue from Biomimetic Modeling, Vincent 2003	53
Figure 10: Boxfish courtesy of www.daimler.com 2008.....	57
Figure 11: Bionic Car courtesy of www.daimler.com 2008	57
Figure 12: building demolition concept from Hochschule.....	58
Figure 13: The surface of the Lotus Leaf, http://www.botanik.uni-bonn.de/system/bionics.htm - accessed January 2007.....	59
Figure 14: Microfluidic actuators based on the cilia of <i>Paramecium</i> - courtesy of Philips 2007	61
Figure 15: Millennium Bridge in Gateshead, UK showing the eyelid design	63
Figure 16: Tree like structure at Stuttgart Airport courtesy of Matthias Gester P&G 2007.....	64
Figure 17: Process used to develop biomimetic models based on current business issues	67
Figure 18: Symbiosis model used in cases	74

Figure 19: Poison Adaptor used in cases	76
Figure 20: Alternation of generations model used in the cases	77
Figure 21: Two Hosted Parasites model used in the cases	78
Figure 22: Past Casting model used in the cases	79
Figure 23: MRS GREN model used in the cases	81
Figure 24: Life stages model used in the cases	82
Figure 25: Test case method as a process	87
Figure 26: Correlation between likely and radical for the senior members of each group	94
Figure 27: Comparison of ideas per group and per person	94
Figure 28: Impact on the three KPI's (number of headings per KPI)	95
Figure 29: Correlation analysis group comparison	97
Figure 30: one of the delegates produced a cartoon capturing the subject	121
Figure 31: Infinity Context Free Process (ICFP)	144
Figure 32: The interconnectedness of systems showing how the models can be used together.....	150
Figure 33: The opportunity to further apply business biomimetics. The circles represent known approaches highlighting the opportunities	154
Figure 34: audience exposure to biomimetic principles before and after the research	165
Figure 35: A sample of pictures used to introduce biomimetics to a business audience, not all of these models have been examined in this thesis	166
Figure 36: Business biomimetics as strategic tools from thinking to changing culture	189
Figure 37: Spectrum of application of biomimetics to show the relationship between value and level of biomimetic abstraction.....	194
Figure 38: Family of business biomimetic models showing MRS GREN as the core model	198

Tables

Table 1: Definitions of nature derived terms.....	20
Table 2: The strengths and weaknesses of using biomimetics as a term	21
Table 3: Current business issues demonstrated by the structure of leading consulting firms in 2004	31
Table 4: The key differences between a product and an ecosystem approach after Moore 1996.....	37
Table 5: MRS GREN characteristics of life from Roberts 1977	39
Table 6: The structure and function of a cell	40
Table 7: Principles of nature from Benyus 1997	54
Table 8: CD for a range of popular cars	56
Table 9: Alignment of biological and business structure	66
Table 10: Aligning biological systems with business problems – linking the business problems with the models	68
Table 11: Model selection criteria	69
Table 12: translating the business issue into the biomimetic model	70
Table 13: This table shows all the models used by the three groups (random selection by the group)	91
Table 14: Evaluation grid used to test validity of ideas.	92
Table 15: Comparison of ideas for the three groups	95
Table 16: Number of ideas and headings per model, biomimetic (A), business (B), control (C).....	97
Table 17: Comparing themes from each group to determine the control effect. Control Group C in the left column compared to the Biomimetic (Group A) and Management (Group C)	98
Table 18: Group A selected themes with original headings	100
Table 19: Group A survey results	101

Table 20: Group A themes generated by model	105
Table 21: Correlation analysis for Group A	105
Table 22: Group B selected themes and original heading	106
Table 23: Group B survey results	107
Table 24: Group B themes generated by model	110
Table 25: Correlation analysis for Group B	110
Table 26: Group C selected themes with original headings	111
Table 27: Group C survey results	112
Table 28: Group C themes generated by model	114
Table 29: Correlation analysis for Group C	115
Table 30: Case study organisations and their key business issues	119
Table 31: Differences in number of ideas for the brewery.....	134
Table 32: Number of ideas for the brewery at each stage showing biomimetics was the highest	134
Table 33: Number ideas that were actually implemented by the brewery.....	135
Table 34: Summary of the business biomimetic models used in the Test Case and case studies	138
Table 35: Future work for the business biomimetic models	156
Table 36: The application of Symbiosis with an IT team	159
Table 37: IT consultancy use MRS GREN to identify strategic gaps.....	161
Table 38: IT consultancy use business biomimetic models to identify themes.....	162
Table 39: The total use of business biomimetic models in the PhD	163
Table 40: The 'Top Thirteen' innovation themes	168
Table 41: Contradiction matrix for bus seat back design identifying the principles after Sen 2003	172
Table 42: TRIZ principles & MRS GREN characteristics. TRIZ Biology, Engineering and Management.....	174

Table 43: The Eight Steps for Successful Large-Scale Change after Kotter 2002.....	176
Table 44: The relationship between business issues and biological systems.....	187
Table 45: The business biomimetic models and their business application.....	187
Table 46: Different ways of applying biomimetics based on the business need.....	195
Table 47: Group A initial ideas	213
Table 48: Group B initial ideas	216
Table 49: Group C initial ideas	219
Table 50: Strategy models used by the Open University MBA.....	221
Table 51: Examples of symbiotic systems.....	225

Chapter 1 Introduction

This thesis is concerned with the application of nature to business. It investigates whether the creation of new business models based on biological systems can be used to stimulate strategic thinking for business leaders. It is a study that researches the current state of management science and asks if the successful practice of biomimetics, which is the application of biological systems to engineering problems, can also be applied at the business level.

Objectives

There were a number of objectives for this thesis. The primary objective was to apply biomimetics to business and see if it worked and whether it generated benefit for the business and how significant this benefit could be. The key measure for this was number of ideas generated and whether these ideas would be taken forward for implementation. The hypothesis was to test business biomimetics against traditional management models to show that business biomimetics would generate ideas that would improve the business performance in terms of revenue, esteem and publications (see page 15 for an explanation of these key performance indicators). The focus for testing this objective was the key strategic business issues faced in the UK in 2004.

The secondary objectives that supported this key objective were-

- To develop biomimetic models for testing
- To compare traditional management models with biomimetic models
- To examine the ideas produced by biomimetic models
- To demonstrate that biomimetic models could add value for business
- To stimulate management thinking using biomimetics

Background

My own background is a mixture of biology and business. I have a BSc in Applied Biology and have always had an interest in the natural world and how we fit in it. I am a Chartered Biologist with the Society of Biology. My career so far has predominantly been in the business sector where I have gained much commercial experience. Much of this experience has been specifically in consulting and I have worked for a wide range of clients in a wide range of industries. I have been employed by major consulting firms and I currently have my own consultancy, Thoughtcrew Ltd, working for mainly large corporate clients. I also am a lecturer in strategy on the MBA course for the Open University. There were two research

methods used in the thesis. The first was a classic experimental design to test the hypothesis that biomimetics could generate ideas and compared this to the ideas generated by traditional business models. The other was case studies where a number of businesses were tested with both business biomimetic and traditional management models. The pros and cons of this approach are discussed in Chapter 10 (page 191).

This thesis shows that biomimetics can be successfully applied to business and that this creates an improvement in the condition of the business. This was achieved by developing a range of business biomimetic models based on the principles of biomimetics using current business issues. These business biomimetic models when applied against the business issues generated a number of new possible solutions.

One of the significant benefits to emerge from this work is not the toolset of models originally envisaged but the introduction of biomimetics to a much wider audience and the development of a process to translate between business and biology. The consequence of this wider audience engagement could be argued as being the birth of biomimetics into mainstream business management.

What emerges from this research is that by studying natural models we can draw parallels for business. Many of the more traditional models examined in management practice, particularly those in the management of the customer and strategy, tend to be based on traditional manufacturing industry. They do not align as well to the dynamic, information rich service economy.

The work has identified a number of interesting biological models that provide the basis of further study in the development of biologically based management models. This thesis is concerned with the potential application of biomimetic principles to strategic business management. It focuses on the development of business biomimetic models, bringing together biology and management and then evaluates the ideas generated to see what impact the new approach has on the development of innovative strategic ideas.

The research examined three research groups based at the University of Bath. They were selected for their similarity in size and structure and because they exhibited all the attributes of a business. The research groups needed to create a marketable product or service, generate revenue, attract and retain customers whilst managing costs. Biomimetic models were created based on the key business issues present in the business community in 2004. They were developed from the analysis of the leading consulting organisations services.

The groups were then randomly allocated as control, conventional business models or business biomimetics models and the results in terms of ideas generated were compared. At the same time, a number of field trials were carried out across a range of industries. Whilst these trials could not be controlled in the same way as the main research groups they do provide valuable insight into the application in the complex world of business.

The results from both the test case and the case studies demonstrated that there is a benefit to be gained from the development and application of biomimetic business models. It was found that a broader and richer range of ideas were generated compared to conventional management models. The business biomimetic approach also generated an increase in the enthusiasm and engagement of management teams in tackling problems that had proven difficult in the past. In this context, business biomimetics provided a mechanism to generate leadership inspiration and provoked a fresh challenge to traditional ways of thinking and doing business.

There is also a viable future in the development of more models for the definition of strategy, the management of change programmes and in the application of functionally based product and service design. The potential is to create an adjunct to conventional management thinking in terms of a robust method and a rich data source of ideas and inspiration. Conventional models produced better short-term revenue ideas and this suggests that a combination of conventional approaches and business biomimetic models would provide the best solution.

The thesis starts with a review of management science and focuses specifically on the development of strategy. Key industry issues are identified by using the current services offered by large consulting firms as indicators about what is important to industry leaders. The use of biology in management science is explored and that leads the thinking into the broader aspect of biological systems and a discussion of their possibilities. Biomimetics is introduced by looking at its application in engineering. In this context, biomimetics is taken as the application of biological systems to solving problems. Having discovered a wide range of business issues and seen how biomimetics has been applied to address engineering issues an hypothesis is developed proposing that the concepts of biomimetics can be applied to business issues. The hypothesis focuses specifically on strategy development and the application of biomimetics to deliver a richer set of ideas.

The materials and methods used to test the hypothesis are described and the fieldwork that was carried out in parallel, in the form of case studies, is explained. The Open University MBA strategy course was used to frame the scope of the business models and four were selected based on their relevance to the identified business problems. The same business problems were then used to help identify possible biological systems. These systems were then transformed into eight business biomimetics models. To test the hypothesis, traditional management models were compared to the newly created business biomimetic models and a control. To evaluate the models the selected research groups at the University of Bath were randomly allocated to the three test variables; traditional models, business biomimetic models and control. This PhD was completed on a part time basis which also provided the opportunity to test the hypothesis with a number of Thoughtcrew's¹ clients. In both cases, the key measure was the production of strategic ideas and how well they addressed the key performance indicators of the business issue.

Two sets of results were generated and these are presented for the test case data and for the case studies. The test case study shows that the business biomimetic models generate a richer set of strategic ideas as determined by their impact on the long-term viability of the research group. This is also reflected in the results from the case studies with one case showing the full life cycle from problem definition to solution implementation. The business biomimetic models generate a significantly larger number of ideas for the esteem measure suggesting that they provide a contribution to the creation of ideas that have longer-term viability. The results suggests that the hypothesis is proven and that new strategy models based on biological systems do generate strategic ideas in addition to those generated by traditional management models. These business biomimetic models seem to generate ideas that are more aligned to the long-term sustainability of the business and support the fitness for the future theme. A new process is also introduced and the possibilities of further development and future application are explored in the discussion.

The current situation with biomimetics and how that may influence thinking is discussed. The argument about analogy versus mimicry is expanded and a possible way of integrating business biomimetics with innovation methods such as TRIZ is presented. Alternative theories on evolution provide insight into different ways of thinking about fitness for the future. Lessons from nature on interconnectedness highlight fundamental gaps in business design and function. The importance of problem definition and the determination of appropriate performance indicators highlight other weaknesses in management practice. The competitors to business

¹ The author was employed by Thoughtcrew at the time of the PhD

biomimetics are considered and the limitations of current biomimetic work are examined. The core argument to be addressed is whether business biomimetics can provide a credible, practical way of creating businesses that are fit for the future.

Further case studies are introduced as the research is applied to live customer situations. An update on progress is provided on the further development of business biomimetics. The results are encouraging and show that conventional management and business biomimetics can be applied successfully across a range of strategic business issues. Work is also underway on developing the ideas into a robust consulting model engaging a wider European group of collaborators. The new case work, using business biomimetics, also identified a number of new areas for its application. One key area was sustainability where business biomimetics provides a useful framework for developing a commercially sustainable business. The applicability to a wider range of functions improves the accessibility for biomimetics for business. The thesis concludes with insight into how the work will be taken forward and how business biomimetic thinking provides the principles for creating the future for business.

What is biomimetics?

Reis captures the essence of the subject in asking “Who better than Nature can design complex structures and control the intricate phenomena (processing routes) that lead to the final shape and structure (from the macro to the nano level) of living creatures?”(Reis 2003)

Biomimetics is the transfer from biology into another discipline such as engineering or architecture. There are a number of words that are used to describe this which are biomimetics, bionics, bioanalogy and bioinspiration.

One of the challenges in describing this area of research is to align it with an accepted description. Biomimetics has been used extensively in the UK to describe the application of nature whereas in mainland Europe and the US, the term Bionics is used more widely. Bioanalogy describes this work well as it is more about analogy than mimicry.

Below is a selection of terms used with their meanings. Whilst they all differ in terms of the emphasis, the common theme is concerned with nature and some form of copying or abstraction.

Term	Proponent	Definition	Reference
Biomimetics	Julian Vincent	“Biomimetics is the technological outcome of the act of borrowing or stealing ideas from nature”	(Vincent 2001)
Biomimetics	Julian Vincent	Biomimetics is the abstraction of good design from nature	(University of Reading)
Biomimetics	Julian Vincent	it's the concept of taking ideas from nature and implementing them in another technology such as engineering, design, computing, etc.	(University of Bath 2007)
Biomimetics	Radio 4 interview with Professor Julian Vincent	the study of how processes and organisms in nature can provide a model for scientific advance	(Philips 1998)
Bionics	Wikipedia	is the application of <u>methods</u> and systems found in <u>nature</u> to the study and design of <u>engineering</u> systems and modern <u>technology</u>	(Wikipedia n.d.)
Biomimetics	www.thoughtcrew.net	The application of biology to business	(Richardson 2007)
Biomimetics	Otto Schmitt	“The mimicry of life”	(Schmitt 1969)
Bionics	Jack Steele	“He defined it as the science of systems which have some function copied from nature, or which represent characteristics of natural systems or their analogues.”	(Vincent, Bogatyrev et al. 2006)
Biomimetics	Dr. Morley O. Stone of the Air Force Research Laboratory's Materials and Manufacturing Directorate	“Biomimetics is the study of the structure and function of biological materials for the purpose of similar synthetic design and manufacturing”	(Stone 2007)
Bioinspiration	Bioinspiration & Biomimetics	“Scientists and engineers are increasingly turning to nature for inspiration. The solutions arrived at by natural selection are often a good starting point in the search for answers to scientific and technical problems. Equally, designing and building bioinspired devices or systems can tell us more about the original animal or plant model.”	(Bar-Cohen 2006)

Table 1: Definitions of nature derived terms

	Strength	Weakness
Biomimetics	Used in the English speaking world. Recognisable in the research community on the UK	Tends to be used primarily for mimicry. How can the biological model be mimicked in engineering, architecture or material science
Bionics	Significant amount of work produced by both academics and practitioners. Non English speaking communities looking to have this as their standard term	Tends to be concerned with technology, such as robots
Bioanalogy	Better describes the work in that the models are analogies rather than mimics	Much lower visibility as a name. Pushed the work out of the mainstream into a niche area. Less acceptable a term

Table 2: The strengths and weaknesses of using biomimetics as a term

Biomimetics would have the higher level of acceptability and bioanalogy would be the most appropriate description. Logically bioanalogy would be the appropriate choice however to simplify communication and acceptability, biomimetics is used throughout the thesis. This use of terminology was discussed at length with Professor Julian Vincent who agreed that biomimetics was the most suitable term to use.

In the US, biomimicry is often used to describe biomimetics. The Institute of Biomimicry has established itself as the expert in this field with Janine Benyus as the principal. It is therefore relevant to consider the biomimicry view to determine whether this informs the overall view.

Biomimicry

Benyus proposes the seven rules of nature as a way to help define how man should change to embrace the patterns of nature.(Benyus 1997) In the book Biomimicry, Benyus explores a number of examples of how success has been achieved across a range of disciplines from underwater adhesive based on mussels to developments based on photosynthesis searching for new energy generation systems. The examples are real, farmers changing the diversity of plants to improve yields, tough proteins based on spider silk and the use of toxins by plants as defensive weapons. Like many involved in the cataloguing of biomimetics (or Biomimicry in this case). There is an eclectic mix of examples that have been drawn back to biological systems. Much of the research approach appears to stem from biologists (with the occasional chemist or physicist) identifying something that may be useful.

Chapter 2 Management science

Current thinking in management

Management or management science as a discipline covers a very wide spectrum. Leadership, strategy formulation, marketing, finance along with process engineering and the management of operations are all essential areas of management. At a simple classification level, management can be divided into two areas strategic and operational.

For the purposes of this work, I have decided to focus on the strategic aspect of management. There were two motivations for this decision. The first is that I believe the key aspect of the biomimetic work will be with senior executives who are more likely to engage with the ideas and will have the ability to ensure business adoption. The second is that much of biomimetic work in the engineering and architecture fields is concerned with operational issues such as product or building design. This focus on business strategy would allow me to make a unique contribution to the body of knowledge on biomimetics.

Strategy is “the determination of the basic long-term goals and objectives of an enterprise, and the adoption of courses of action and the allocation of resources necessary for those goals” (Chandler 1962). It is a process (Porter 1985) that applies to every sub-unit of the business (Andrews 1971). The origin of “strategy” is Strategos which referred to the role of general and later became the ‘art of the general’ (Murray, Know et al. 1999). By 450 BC, it was understood to mean managerial skill and by 330 BC, it covered the skills to overcome opponents by the use of forces and governance. Murray et al (Murray, Know et al. 1999) suggest that strategy involves human values, passion and beliefs. They argue that strategic planning is part of strategy and must be able to cope with the messy realities of uncertainty and variability.

Having narrowed the scope of management down to strategy there is still a wealth of literature, books and organisations espousing the pros and cons of various approaches. At this stage, it is worth noting that in strategy management the standard language of communication is through models and concepts.

The next challenge was to decide what to use as the basis for analysing strategy management. I was looking for a broad appreciation of the latest thinking in 2004 and to do this I started with two sources. The Strategy Reader (Segal-Horn 2004) is the course text book for the Open University Business Schools, MBA programme and Contemporary Strategy Analysis (Grant 2006). As both of these books are standard texts for students studying for an MBA, they represent the accepted state of strategy education for managers. Whilst they do not contain all of the latest thinking, strategy maps (Kaplan 2004) being one notable omission, they are widely recognised as the core source of models and concepts. Analysis of the top international universities and their recommended textbooks confirmed the selection of these models. (Business Week 2004) These two referenced textbooks provided a useful way of establishing context to review the current thinking in strategy and from this review, a number of areas emerged. At this stage, it appeared that the MBA would be a useful way of framing the research scope because there was a comprehensive coverage of strategy.

Over the past fifty years, business has been transformed by the application of technology. Social impact has also driven change and the integration of different cultures has seen the global domination of brands. There have also been changes in economics, the removal of trade barriers and tariffs and the development of social networks which impact on the skills and capabilities needed by managers and leaders. Similarly, change has seen increased pressure on the business community to be more environmentally friendly and customers are more vocal in what they want in terms of both product and service. The approach to the management and leadership of businesses has also changed. The focus has moved steadily from all energy being directed towards products to now encompassing customer relationship management as a key element of the business offering. The changes are being enabled by the use of integrated technology solutions, often referred to as creating an e-business. There is growing pressure on managers to be able to provide profitable results in this evolving environment and to be able to adopt and exploit assets and opportunities to be able to do this. A number of key topics emerge which are central to the management of business. These topics are interrelated and best seen as component parts of the approach to management rather than discrete, independent subjects. Strategy is therefore an essential part of the leadership and success of a business. For the purposes of this thesis strategy will be viewed as a process (Mintzberg, Quinn & Ghoshal 1998)

The strategy process

The strategy process covers analysing, choosing and implementing (Johnson and Scholes 1993) in the context (Pettigrew 1988). The process, shown in Figure 1, starts with a deep understanding of the external environment. This analysis is aided by the use of models such as STEP (Fahey and Narayanan 1986) and 5 Forces (Porter 1980).

Next, the internal environment is analysed. This includes a review of the resources, capabilities and knowledge held by the business. By comparing the external environment with the internal environment, one can see the strategic issues that the business faces. At this stage, it is important to understand the stakeholders and their claims over the business. This is done by determining their power (Winstanley 1995) and their salience (Mitchell, Agle et al. 1997). Saliency is the power a stakeholder has over the actions of the business, its legitimacy in terms of legal or moral grounds and the urgency which a business feels it needs to respond. Having determined the strategic issues and the potential impact of stakeholder, the options for corporate strategy can be explored. The product/market matrix (Ansoff 1965) is particularly useful as it helps decide which products or services (existing or new) to sell in which markets (existing or new). It is also used to review diversification options such as joint ventures, alliances and coalitions. At this point the mission of the business is considered as this could have a fundamental impact on the shape of the strategy (Campbell and Yeung 1991). An example of this is a charity. The beliefs and values of the charity will have an impact on the scope of the strategy, the priority of investment and the key success factors. The mission considers what the business believes in, why the company exists, the policies and behaviour and the distinctive competency required.

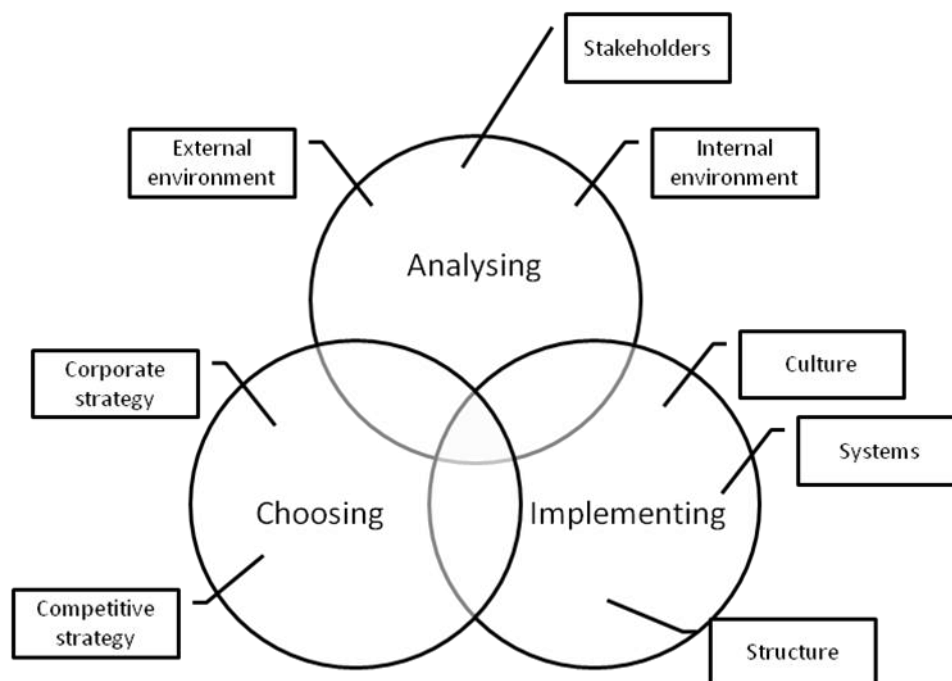


Figure 1: The strategy process after Johnson & Scholes 1993

A corporate strategy decision is taken after evaluating the established testing models (Johnson and Scholes 1993; Rumelt 1995; Lynch 1997). These approaches to evaluation look at suitability, feasibility and acceptability as well as business and finance risk and the long-term social impacts of the choice. With the corporate strategy defined, it is then possible to decide the competitive strategy. Generic strategies proposed by Porter (Porter 1985) or later adapted by (Hitt, Ireland et al.

2003) are used to decide whether the business competed on the basis of cost or differentiation in a broad or narrow market.

The final stage in the strategy process is implementation. This requires an understanding of the culture, systems and structure of the existing business (the as-is) and a design for the new culture, systems and structure (the to-be). Analysis of the culture can be facilitated with the use of the Culture Web (Johnson 2004) and an understanding of the process of culture change (Wheelan and Hunger 2002). Resistance to change will need to be considered (Whipp 2003). The role of the leader is important in managing the inter-relationships between culture, systems and change (Johnson 2004). Major hurdles can be overcome using tipping point leadership (Kim and Mauborgne 2003). With the appropriate organisational structure being aligned to the corporate strategy. This structure can range from a machine bureaucracy (Mintzberg 1979) where the business is controlled rigidly from the centre, to an adhocracy where the organisation is actively encouraged to be flexible to the demands of the market through the collaboration between senior management, middle management the operating part of the business and the technology and processes of the business. The balance of control between the beliefs of the business, its measures, the control systems and the corporate boundary are then managed to ensure the business strategy is delivered (Simons 1994). These operational systems and control provide the link between the strategy and the operational effectiveness (Grant 2002).

The external environment (Mercer 1992) encompasses the market (Kotler 1988), the industry (Porter 1985) and the competition. social, technological, political and economic aspects in which a business operates (Fahey and Narayanan 1986). Marketing plays a key role in a business that needs to be able to understand and operate within the external environment. The analysis, planning and control aspects of the market are key to understanding customers and developing products and services (Kotler 1988). This understanding of the customer provides a basis by which a business can dominate its chosen market place (Treacy 1995). The need to understand the customer and to operate as a customer-centric organisation has forced many businesses to re-think how they operate and the products they provide. The businesses need to drive customer loyalty (Stotland 2001) and this is now seen as a core requirement. The external environment is a critical consideration for the survival of a business enterprise. Businesses that are more in tune with the external environment are more likely to be successful (Mercer 1992).

Blue Ocean Strategy (Kim and Mauborgne 2005) takes a different view of competition in the external environment. This approach suggests that companies should create new market spaces that avoids head-to-head competition. The Blue

Ocean strategy challenges traditional competition based strategic thinking. The aim is to make competition irrelevant. The focus is on the “blue oceans” which are markets, which do not exist today. Kim and Mauborgne also raise the notion that many of today’s industries did not exist thirty years ago and the challenge exists of what the next fifty years will bring.

In the internal environment, a business needs to understand its resources and capabilities if it is to create successful strategies (Grant 2008). By understanding the resources and how they can be configured into capabilities, the business is able to determine how it can best match the opportunities that exist in the external environment. Those resources that are lacking can then be developed and new capabilities created. The resources could be internal to the company or part of the company’s value chain (Porter 1980). Porter’s work was based on the car industry where components were bought and then processed through various stages. At each stage, value was added and therefore the result, which was a complete car, was worth far more to the customer than the individual components.

Once understood, the gap between the external and internal environments provides the basis of strategic analysis (Segal-Horn 2004) which is presented as the strategic issues. Having understood the external and internal environments, the challenge is to define and choose the appropriate strategy which will address these issues.

Mintzberg et al believe that a range of concepts is needed to be able to understand the complexity of organisations. In the Open University MBA course on strategy, there are 98 models and concepts. The challenge is to decide which are the most appropriate to a given situation. It is important to have the appropriate knowledge and skills both to apply the models and to analyse the data. This analysis requires the ability to understand tangible and intangible assets and their interrelatedness.

More than 75% of a company’s market value is built on assets that are intangible (Kaplan 2004). Strategy is the bringing together of these intangible resources which encompass such areas as brand, patents and intellectual property with tangible resources such as machinery and people that will create a capability. Kaplan and Norton have demonstrated that their initial Balanced Scorecard principle (Kaplan 1996) coupled with Strategy Maps (Kaplan 2004) providing managers with the much needed tools to define and deliver successful strategies. This approach highlights the need to develop not only the concept but also the tools to deliver the concept in context. The Strategy Maps link the value of the business with their financial goals.

They also incorporate the impact on internal processes and customers. Therefore, for the business it will be necessary to not only create the model and the tools but also show the context and how to get a 'joined-up' approach. Strategy also needs to provide alignment (Kaplan 2006) between the different parts of an organisation. Optimising one could cause detriment to the other.

The role of strategy has changed as small businesses have developed into larger corporations. It has been argued that corporations have evolved (Grant 2008). Grant compares the present day enterprises that produce goods and services, often on a global scale, with the Roman Catholic Church, national armies and a small number of trading companies. The suggestion is that the present-day corporations have evolved as a way of optimising survival. By analogy this microcosm of evolution draws the Darwinian theory (Darwin 1859) from biology right into management science and raises the possibility that it may be possible to model the future of business using the natural world as a template. Similarly the industry life cycle (Grant 2008) from introduction through growth, maturity and then decline exhibits a similar profile to that of a species at one level and the colonisation of an area at another.

Business survival is a key component of strategy. It is often quoted as one of the fundamental driving principles behind the creation of strategy (Lynch 1997). Survival for a business is a constant battle with its environment. Lynch suggests that those best adapted to the environment and most willing to change are most likely to survive. This means that those that do not create a strategy that adapts to the environment are effectively making a strategic choice of eventual extinction. Therefore it is the adaptive enterprise (Haeckel 1999) that is capable of both sensing and responding to changes in the environment that improves its survival. The combination of adaptation with selection could then be a powerful source of advantage for a business. It is worth noting that nature's adaptation is 'good enough' (Vincent and Mann 2002) and not over engineered therefore if this is applied to a business situation it is not often appropriate or desirable to dramatically change everything in a business but better to be constantly aware of the environment both within and surrounding the business and change enough to survive. Strategy and the environment are inextricably linked to survival.

Strategy is a candidate for the application of biology where the possibility exists to develop biomimetic models that drive strategy formulation. Having created a suitable strategy the worth is realised only when the strategy is implemented. The implementation is a change between the current business and the new business and is referred to as change management. Typically, change management can affect

processes, procedures, organisation design, people, culture, data use, technology infrastructure, finance and the product and customer mix.

Academic research fuelled by consultancies has long been the source of innovation for business. Whilst it could be argued that this approach has been around only since the 1960's it has become an established way of working. Typically, observations on how groups of businesses perform are assimilated into a pattern or model. This model either is then presented as a 'silver bullet' for a particular problem or is then applied to a number of similar situations to show the efficacy of the model. There is also a booming industry in presenting these ideas in books. It could be argued that this is the 'business of doing business'. This way research in universities is encouraged and the application of this research through management consultancies is a very profitable business due to the impact on commerce.

Other approaches include those based on logical deduction and applied thinking where new models are created by testing hypothesis of how business works. These are then applied to business situations and the results measured. Over time the models and concepts merge, spawning further new or hybrid ideas. Examples include: supply chain management, customer relationship management, e-business, strategy, corporate social responsibility and business process re-engineering. There is a constant demand for the latest thinking, providing a sustainable revenue stream for both academia and the consulting professions. In 2006 the consulting market in the UK was estimated at £14 billion (Consulting Central 2006). Professional service firms, including consulting, need to compete in two markets, the clients which benefit from the output of its services and the professional workforce that provide the customised work for clients (Maister 1982). These factors are balanced by the firm's economic and organisational structures. Because of this balance the services provided by the consulting firms are representative of the needs of the marketplace.

As the use of models is the accepted mechanism of communicating ideas in business then it was appropriate to use models as the way of testing the idea that nature could boost business performance. The Open University Business School (OUBS) is widely acknowledged as Europe's largest business school (Which-MBA? 2008). It is a 'gold standard' business school. According to the Association of MBAs, the global accreditation body for business schools, the Open University is in the top 1% for quality. "The OU Business School is accredited by the world's top management education associations – AACSB, EQUIS and AMBA – an achievement that puts us in an elite group". (Which-MBA? 2008)

The OUBS strategy course forms part of the second year of the MBA programme. It is a mixture of distance learning, e-learning and face-to-face tuition. Completion of the course requires passing a series of continuous assessment assignments and an end of course exam (Open University Business School 2008). The top five Universities from the Financial Times Global Business School Rankings of 2004 (Business Week 2004) were examined to see what they used as their business models for education on the MBA programme. Each of the Universities has its own publisher and this skewed the answer. However, the key authors used by the Open University were also referred to in each of the top five schools. In two of the five cases, the same textbooks were used. On this basis, the Open University was chosen as representing education to MBA students in strategy.

Conventional wisdom

Conventional teaching for managers tends to use case studies, models and concepts to provide tools and approaches to deal with business challenges, well known examples include Porter's Five Forces Model (Porter 1980) and Ansoff's Growth Vectors (Ansoff 1965). Much of the research in management science in the UK is based on the manufacturing industry. This is currently changing as business throughout the Western world and in the UK particularly, is moving to service based operations. Operations management is important to all businesses (Slack, Chambers et al. 2004) and the manufacturing models are now being adapted so they apply to the production of products and services. Whilst a number of models are grounded in manufacturing, they are finding favour in the new service economy.

The search for something new

This work focuses on a subset of management science as shown in Figure 2. It takes the area of strategy and looks at idea generation to solve problems of growth. The reason for choosing this subset of management was because all of the key decision makers in industry are involved in the formulation and implementation of strategy thus this work would have the broadest appeal.

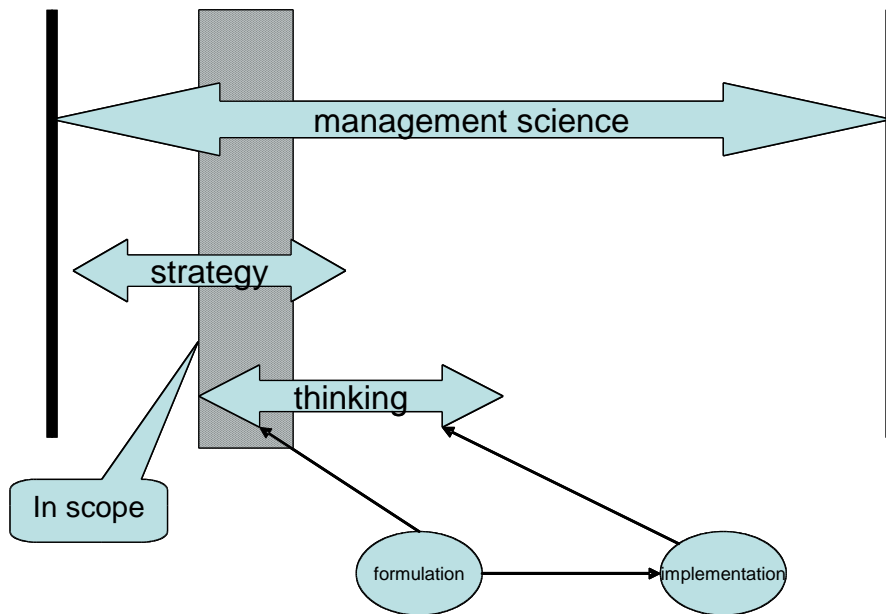


Figure 2: Scope of management science

The approach is to select a number of these models as the basis for comparison. The models were selected based on their close relationship with strategic thinking. Thinking, according to Senge, is the role of the leader who brings challenge, particularly to prevailing models of thinking (Senge 1990) and, where appropriate, provides the resources to solve the business problems and drive the success of business opportunities.

Identifying the business issues

Whilst at first there seemed to be a wealth of different issues in business, a useful benchmark is the current practice structure of leading consulting firms, on the basis that the consulting firms will be developing services to address what are either the actual or perceived business issues. Three leading consulting firms were examined to see where they were concentrating their services. Table 3 shows the current areas of consulting services as offered by the different consultancies.

Accenture	Capgemini	IBM
Change management	Transformation consulting	Revitalize your business
Corporate strategy		Exploit your capabilities
Customer relationship management	Customer relationship management	Strengthen your customer connections
Enterprise performance management		Secure your enterprise
Finance management	Finance and employee transformation	
Global delivery and sourcing	Global sourcing	
Human resources management	Finance and employee transformation	Transform your workforce
Service management		
Shareholder value		
Supply chain management	Supply chain	Manage your operations
	Outsourcing services	
	Local professional services	
	Technology services	Technology services
Workforce performance	Operational research	Transform your workforce

Table 3: Current business issues demonstrated by the structure of leading consulting firms in 2004

There is clear overlap between the practice structures and product offerings of these leading consultancies. The key business issues distilled from this analysis can then be defined as

- Working across functions
- Joint ventures and collaboration
- Competition
- Resources and capabilities
- Growth and sustainable competitive advantage
- Integrated supply chain
- Where does value come from, becoming customer centric

Selected business models

Based on the initial analysis of current business issues, where the top strategic issues were identified, a selection was made from frameworks that are used by the Open University to teach strategy to MBA students. In consultation with a number of associate lecturers for the Open University, these were seen as the conventional core models used in analysing, appraising and evaluating the development of strategy. There were four different models selected based on their alignment with the identified business issues.

Porter's five forces (Porter 1980)

The five forces model, shown in Figure 3, provides a framework to analyse the attractiveness of an industry. It can be used to evaluate the opportunity a company faces in entering a new industry. It can also be used by companies already competing in an industry to evaluate their competitive position. As the model is static it is more useful when applied at different points in time.

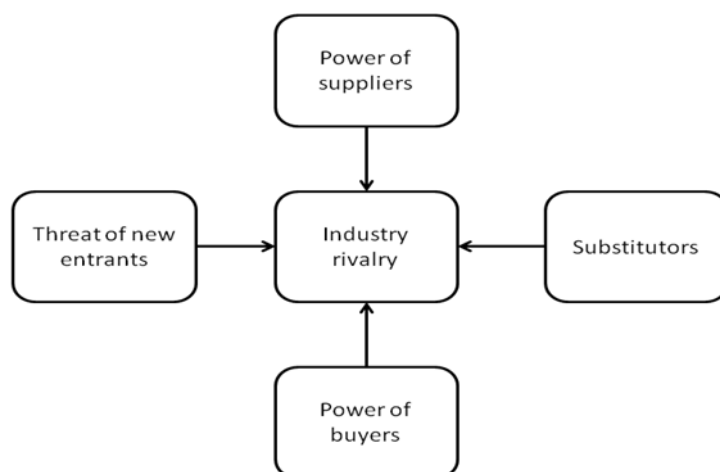


Figure 3 Strategy Model based on Porter's 5 Forces 1980 showing the forces that shape an industry.

It is used as part of the analysis of the external environment and useful in flushing out barriers to market entry. The relative strength of buyers and suppliers can be assessed and helps gauge whether substitute products and services will affect the attractiveness of the market.

A resource based approach to strategy analysis (Grant 2006)

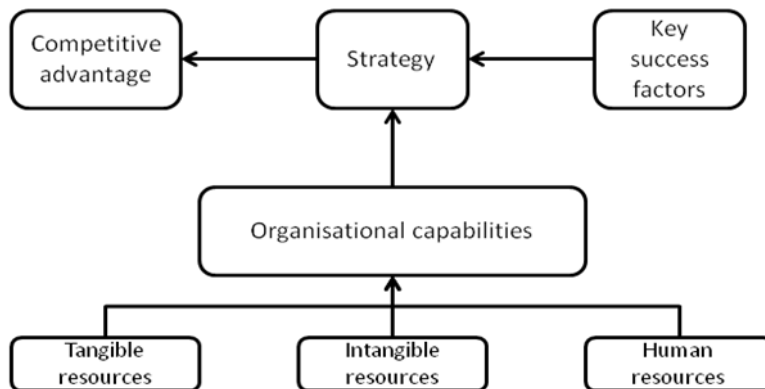


Figure 4 A Resource based approach to strategy based on Grant 2006.

The resource-based approach, shown in Figure 4, is used to analyse the internal resources and capability of a business. It identifies three classifications of resources and then shows how these are combined to create a capability that can then deliver a defined strategy. When the strategy is compared to the key success factors of the industry the degree of competitive advantage can be measured.

A general model of the value chain

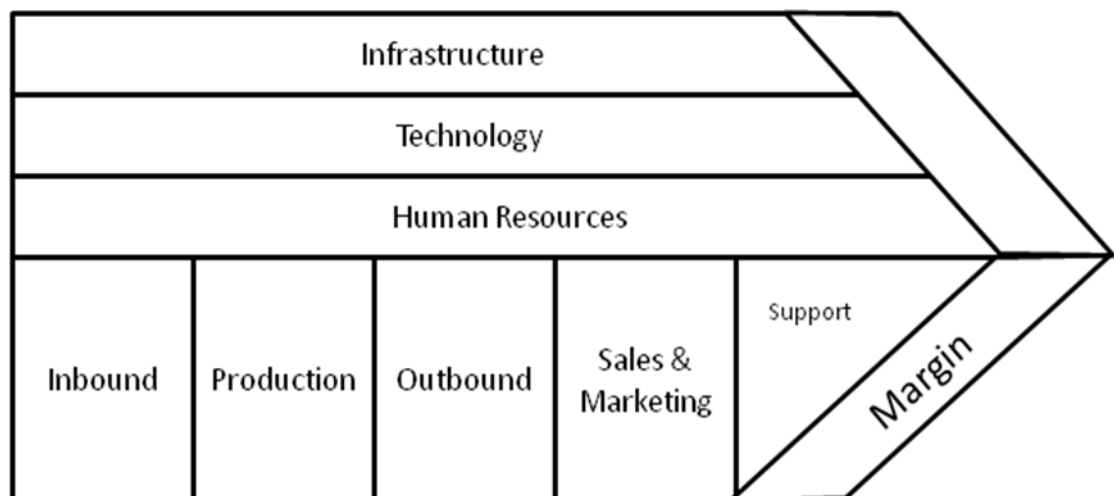


Figure 5 A general model of a value chain after Porter 1985. The model is drawn as an arrow because it shows the flow of value towards the customer and profitability.

The value chain, shown in Figure 5 is used to determine which parts of the business add value from a customer perspective. The model assumes that value is consistently added from left to right. The model can be used to find out if this is the case for a particular business. Each step from the left to the right adds increasing value. The functions that run across the model are essential to facilitate the value adding steps.

Key success factors

Key success factors are different from key performance indicators in that they measure the factors that are key to success in the market. Figure 6 shows the Grant model for determining key success factors based on an understanding of customers and competitors. This then provides firms with a basis for understanding what will make them a success in the market.

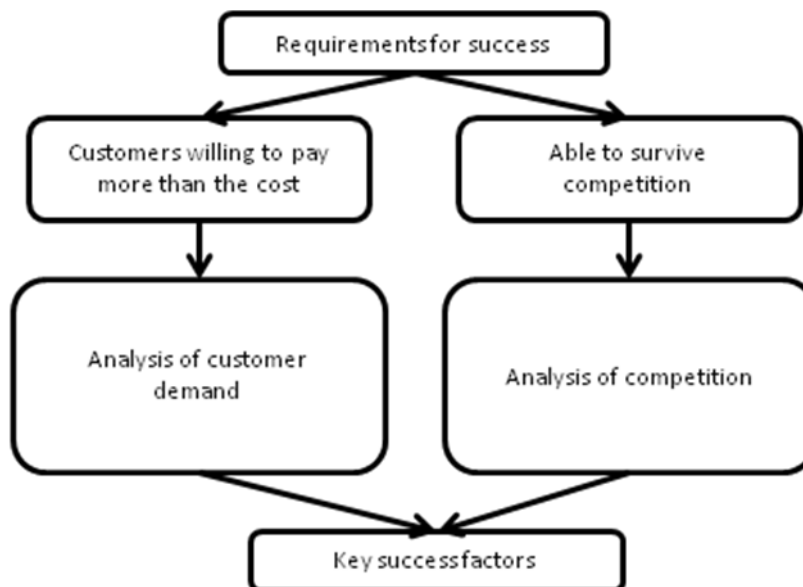


Figure 6 Identifying Key Success Factors after Grant 1995.

These factors in Figure 6 are important in that they help a firm identify whether it has implemented a successful strategy. To do this Grant advocates understanding both the customers and the competitors.

Selecting the strategy models

The task of selecting a representative selection of models for the comparison presented a challenge. A list of the most commonly used models used to answer strategy-based questions was drawn up from MBA students. Ninety assignments completed by MBA students were examined to see which models were the most appropriate when applied to their own organisations. Every student examined used the four models selected.

Management and biology

The thesis is exploring the application of biology to business by expanding the field of biomimetics. The use of biology to help business is not a new approach and a number of examples exist where biological systems have previously been used as an analogy or a metaphor for business (Woll 2003). In reviewing, the work there was a surprising lack of material that was based on robust biological knowledge. In the main, the work was at best based on a popular science viewpoint where general knowledge of biology had been applied to an observed situation in business. The most common aspect was the application of the ecosystems, a metaphor for the business environment (Clippinger 1999). There are also attempts to link the ecosystem approach to the need to understand the external environment (Hagros and Osterman 2003). In both cases, the emphasis is on the interrelatedness of systems and in the case of Clippinger the development of this to identify why understanding the complexity of the systems is important and how the ability to adapt the system might generate a new approach to management.

Management Systems

According to Clippinger, biology became the new place to look for organisational inspiration. Looking at self organising processes (Clippinger 1999) he suggests that there is a need to make a radical departure from conventional top down management thinking. He questions how developers throughout the world can develop a computer operating system called Linux without any significant investment, when Microsoft and IBM have both spent billions of dollars doing the same (and IBM's was not successful). Called Complex Adaptive Systems (CAS), this new thinking challenges the fundamental approach businesses take to being organised and the way in which they now need to proceed. This thinking predates the wisdom of crowd's approach that suggests that rather than turn to a leader to get a problem solved you turn to the crowd. (Surowiecki 2004)

These complex systems and their adaptive behaviour seem to be more aligned to the relationship that species have with other organisms and the environment rather than just another individual organism. Here Clippinger argues that the goals and policies are "bottom up" and are emergent. This shows parallels to Darwin's thinking of natural selection (Darwin 1859). The key is more fitness for the future and not adaptation to the past. It could therefore be argued that the focus needs to be on complex fitness systems as adaptation must always be retrospective. Adaptation in biology is the phenomenon whereby a random mutation happens to be useful, and therefore is selected over successive generations.

The death of competition

The term business ecosystems was introduced to propose that conditions that exist in the fiercely competitive sectors are likely to spread to all industries.(Moore 1996) Business boundaries, as described by earlier theories (Mintzberg 1979; Porter 1985; Johnson and Scholes 1993) are disappearing as companies spread to exploit areas of opportunity. This innovation driven by competition (Hagros and Osterman 2003) is seen as distinctly different to product innovation and is driving new behaviours in developing speed and innovation rather than the traditional focus on costs. This significantly changes the view on who is the competition and would need a radical change in the environmental scanning that many businesses carry out. It also has a significant impact on resources as many organisations will have built resources and capability on the cost focused approach.

Because of this there is a need to better understand the economic environment as opposed to drilling down to the market or industry (Hagros and Osterman 2003). Microsoft is an example of a business that is in software such as games, consumer electronics, information, communication and web technologies. Hagros argues that they are therefore focused on a business ecosystem. Moore states that the core success is based on the ability to create value that enables others to generate even more value (Moore 1996). The focus for Hagros is corporate strategic planning and he states that so long as circumstances remain unchanged a company can remain successful and profitable. This links with the idea that nature also stays constant until there is a need for change. Much of the thinking around planning works on the ability to predict what changes might occur then plan for those possibilities however; this approach fails in circumstances where the change is both unexpected and unpredictable. In applying ecosystems to corporate planning, there is a clear need to provide the capability to both sense and response. It therefore follows that this approach to the development of future strategy can only be determined at the instant a change is detected. Business is often fascinated by long-term strategy whereas it could be argued that nature concentrates on offering an immediate response.

Moore suggests that there is a link between company and industry to the ecosystem which is shown in Table 4

From Company & Industry	to Ecosystem
Business boundaries are given	Business boundaries are an issue or a matter of choice
Industry/company is the primary unit of strategy making.	Business ecosystem is the unit of strategy making.
Economic performance depends on internal efficiency and industry profitability.	Performance depends on how the company manages its alliances and relationships.
Company growth is the central concern.	Development of the ecosystem is the central concern, as well as the position of the company within this economic network.
Co-operation is limited to direct suppliers and customers.	Co-operation is expanded to include all players relevant to search for unmet needs.
Competition is seen between products and companies.	Competition is also understood to be among business ecosystems, as well as for leadership within a particular ecosystem.

Table 4: The key differences between a product and an ecosystem approach after Moore 1996

The business ecosystem theory seems to drift from the biological view when both Moore and Hagros state that there is an ecosystem leader and that dominance of an ecosystem is critical for survival. This does not seem to support the definition of ecosystem² and like much of the other work reviewed seems to be post rationale in its application. Ecosystems in the biological sense are a group of living organisms and physical environment where all interact in some way. There are no leaders in an ecosystem. The application of ecosystems to business in this limited analysis done suggests that there is a lack of understanding of the biology of the system.

The wider application of biology in business

Whilst ecosystems dominate the majority of work on biology, in business there are a number of other areas which seem to support the broader adoption of biology as a credible management subject. TRIZ is an inventive problem solving technique based on the principles seen in patents (Altshuller 1999) Recent work (Vincent and Mann 2002) has been an attempt to catalogue biological utility into the TRIZ framework. This approach is further supported (Mann 2001) and subsequently argued by Kaplan that there are parallels between biology and technology evolution, leading to the conclusion that biology is a rich source of inspiration for technology development (Kaplan 2003). There is also a link through TRIZ from the inventive principles to

² A comprehensive summary of definitions can be found in Appendix A

business systems.(Mann and Domb 1999) which means that through TRIZ it is now possible to connect engineering, biology and business as a source of inspiration for the development of products and technology solutions.

More general applications of biology include the use of the neural networks in artificial intelligence systems and the same metaphor is also applied to the brain being the board and the nervous system being the communicating channels to the front line workers. The metaphor (Ouzounis and Mazi 2006) is then further extracted to include the heart, lungs, kidneys and blood systems.

Summary of biology in management

There appears to be little documented evidence for the successful application of biology in management. To date biological systems are used subjectively as a metaphor and do not appear to be based on a detailed understanding of the subject. Another example, such as the use of TRIZ, is more rigorous in the understanding and application of biology. However, there is little in-depth understanding of business issues and as such it perhaps is best suited as an innovation tool and part of a wider innovation strategy (Mintzberg 1979). The challenge remains to bring in-depth biology into management science to provide a real alternative to conventional thinking. This also needs to address the barriers to innovation (Mintzberg 1979) seen in larger organisations and the complexity of business in the current economy.

Chapter 3 How biology might have the answer

Having discussed the current management models that are being used by industry in the previous chapter, the aim of this chapter is to look at biology and begin to explore how biological systems can be related to biomimetics. Some examples are taken from the engineering and architectural worlds to clearly show how biomimetics has already contributed. Once the biological systems have been examined, a link can be established between how nature and business both have to operate in challenging environments.

Biology is the study of life and living organisms. Taken from Biology: A functional approach (Roberts 1977) the characteristics of life are shown in Table 5.

Characteristics of life	Definition
Movement	A characteristic of organisms that they, or some part of them, are capable of moving themselves. Even plants, which at first sight appear to be an exception, display movements within their cells.
Respiration	To stay alive an organism must be able to release energy in a controlled and usable form. Energy is released by the metabolic breakdown of organic compounds
Sensitivity (Responsiveness)	All organisms, including plants, react to stimulation. Such responses range from the growth of a plant towards the light to the rapid withdrawal of one's hand from a hot object. Even the simplest organisms respond to stimuli, as can be seen when examining single celled organisms such as <i>Amoeba</i> or <i>Paramecium</i> under the microscope.
Growth	Growth is the permanent increase in size of an organism in the course of its development. Cell division, assimilation and cell expansion are the three processes involved in growth.
Reproduction	All organisms are able to reproduce themselves. At its simplest form, reproduction involves the replication of certain giant molecules (macromolecules). These molecules are nucleic acids, generally deoxyribonucleic acid (DNA) sometimes ribonucleic acid. The presence of these complex molecules in organisms from viruses to man qualifies them as an essential characteristic of life.
Excretion	The chemical reaction that takes place in organisms resulting in the formation of toxic waste products which must be either eliminated or stored in a harmless form.
Nutrition	Organisms constantly take in and assimilate materials for growth and maintenance. Animals generally feed on ready-made organic matter (heterotrophic nutrition), whereas plants feed on simple inorganic materials which they build up into complex organic molecules (autotrophic nutrition).

Table 5: MRS GREN characteristics of life from Roberts 1977

Understanding the characteristics of life is useful as it forms a checklist for establishing whether something is 'alive'. This MRS GREN checklist will be referred to throughout the thesis because it can be readily applied to the idea of whether a business is 'alive' and therefore viable. As well as looking at the characteristics of life, it is useful to look at parts, or organelles, of a cell³ which make up the basis of life Table 6. The structure and function of the different organelles become the necessary ingredients to come together as the cell (Becker, Kleinsmith et al. 2006).

Part	Structure	Function
Cell wall	Outer boundary of plant cells made of cellulose	Protective, keeps cells in shape, fully permeable
Cell membrane	Very thin layer surrounding cytoplasm	Regulates what enters and leaves cell, partially permeable e.g. O ₂ and CO ₂
Cytoplasm	Granular, jelly like material with nucleus embedded in it	Chemical reactions take place here. Granules may contain stored food
Nucleus	Prominent dark area in cytoplasm	Regulates everything that goes on in the cell
Chromosomes	Thread like structures in the nucleus	Made up of genes inherited from parents, control characteristics
Cell vacuole	Cavity in cell, filled with cell sap. Plant cells often have large permanent vacuoles, animal cells may have several smaller vacuoles	Cell sap contains water, sugar and salts. Control water balance in plants
Chloroplasts (some plants only)	Contains green pigment chlorophyll	Site of photosynthesis. Chlorophyll absorbs light needed for photosynthesis
Mitochondria	Organelle containing many of the enzymes needed for respiration reaction	Release energy for cell

Table 6: The structure and function of a cell

³ Here a prokaryote cell structure was used as the illustration

This structural approach is similar to the one adopted by businesses. It is possible at this stage to see how a business can be designed and how this design maps to the 'parts' of living things. There is a possible alignment between the building blocks of life and the building blocks of a business. Building up from the idea of cell organelles coming together to make an individual cell, this process continues to build into tissues which are a collection of cells working together to carry out a particular function. Organs are made up of different tissues that are grouped together and individual organs work together to make up a biological system. The culmination of the building blocks is the complete organism.

Biological systems were looked at to understand the range of challenges or issues that life or nature has to cope with and which mechanisms have evolved. A deliberately very broad range of systems were analysed so that a truly diverse picture could be established when considering adaptations to challenges. An attempt has been made to loosely fit the response into MRS GREN see Table 5 to give some order to the process. Obviously many more biological systems can be mapped in this way however at this point in the thesis; the idea was to give examples of how nature copes in different situations. Not all of the biological systems examined were subsequently carried forward into the development of the biomimetic models. The following review covers a wide range of biology and is being used to set the context for the later development of the biomimetic models, This will be used to test the hypothesis.

Later on page 66 Table 10: Aligning biological systems with business problems – linking the business problems with the models, shows how the biological systems described below were brought together and aligned against the business issue. The review of biology has been organised by the factors in MRS GREN.

MRS GREN

Movement

Flocks

Flocks of birds can initiate a turn up to three times faster than they can biologically respond to their neighbour. This means that the birds respond faster than the mechanism they have for sensing and responding, which cannot be true. The real mechanism relies on anticipation and a learned response. This could be a source of

building business capability that performs better than the sum of the individual components would indicate. Potts believes that this is due to observation and anticipation and is a phenomenon that can also be observed in the chorus lines of people. (Potts 1984). The move has been seen to be initiated by a single bird. This becomes interesting as a possible basis for a business biomimetic model as the bird is not part of a hierarchy. This model could be applied to business that would allow anyone in the organisation to stop a 'wave' and then initiate a response without reference to any management structure. The chorus line effect as seen in co-ordinated dancers has shown that the response time to the leg movement of the previous girl in line reduces from 198 ms to 108 ms (Teichner 1954). This means that the dancer's response is almost twice as fast as would be expected behaviour. Such a response improvement in a business process would have a significant impact on performance. Observation in flocks also shows a slow start time then acceleration as the wave moves along all axis of the flock. (Potts 1984) This could also be significant for a business in terms of response times and variability in the response. Birds of prey tend to target individuals that are away from the main flock (Krebs and Davies 1993). It could be the basis of a business biomimetic model for competitions.

Fish schooling

The close approximation of fish in a school or shoal is thought to reduce the water pressure thereby using less energy when swimming. However, there is some doubt that this is the case. The key reason is to avoid predation and parasitism (Seppala, Karvonen et al. 2008). These schools or shoals of fish also hunt together and that is more efficient than hunting as a single fish (Krebs and Davies 1993).

Insect swarms

Swarming theory is based on dividing the gap between two others in the swarm. (Gullan and Cranston 2004) This phenomenon is also observed in bacteria. This is the collective behaviour of decentralised self-organising systems. The resultant appears to create an optimal solution. Flocking, schooling and swarms are later utilised in developing the Flocking model (see page 71)

The life cycle of plasmodium has two different hosts

Plasmodium is known to cause malaria. It is carried by two hosts, the mosquito and man. The host is used as a mechanism by which it transfers to the next host and as this is cyclical, the host-to-host mechanisms are continuous. This was used as the basis of developing the Two Hosted model (see page 78). The *Plasmodium* avoids detection by the human immune system by constantly changing its surface proteins (Campbell and Reece 2005).

Respiration

Sea Slugs

Pteraeolidia ianthina, a sea slug is found in the Pacific Ocean. It feeds on plant like animals, known as hydroids, which are closely related to jellyfish. These hydroids contain microscopic marine plankton (dinoflagellates) which are photosynthetic. Photosynthesis continues, as the dinoflagellates exist in a symbiotic relationship with the nudibrach. This provides an energy source for the nudibrach providing a respiration model that is solar powered (Hoegh-Guldberg and Rosalind 1986). Plant hopper insects, Hemiptera and Issidae use energy stored by bending stiff cuticle to jump coupled with muscle control to synchronise the jumping. (Burrows M. 2010) This system has already been the subject of biomimicry as demonstrated in the jumping robots which are explored on page 58). The sea slugs model was used as the basis of both the Poison adaptor (page 75) and symbiosis models (page 73)

Sensitivity

Termites

With the practical challenges of survival in hot and humid environments termites have built in air conditioning to keep the nest at a constant temperature (Gullan and Cranston 2004) see page 319. This is a real example of where nature has solved a challenging product development problem. Evidence that this works can be found at the Eastgate building in Harare, Zimbabwe. This building has followed this design principle and does not need air-conditioning to keep the temperature constant.(Koelman 2004). The termites, *Macrotermes* sp manage to create convection current inside their nest due to the creation of tubules and chambers in the nest wall. (Bonabeau, Theraulaz et al. 1998). Bonabeau et al raise the question whether termites build their nests from a high bank of construction information or from a simple sense and respond mechanism coupled with simple behaviours. Are there product ideas for the release of pheromones in supermarkets based on the termites? The effect would be to cause shoppers to think about buying specific produce based on the strength or type of pheromone received. This builds on the idea of sending the smell of fresh bread baking through vents at the entrance to a store. There is some debate in the biological community about whether humans can detect pheromones using the sense of smell (Stern and McClintock 1998). Whilst this system is not specifically, use to develop a business biomimetic model the principles behind chemical messages are used in the development of the Poison Adaptor model (see page 75)

Growth

Butterflies

A caterpillar becomes a butterfly going through a number of moulting stages before eventually emerging after the final stage of pupation as the butterfly. The interval between larval moulting is the instar and the average number of instars is four. (Brooks and Knight 1982) Because of the substantial changes that take place in pupation it is sometime referred to as the second egg stage. This biological system is a biological analogy for what happens in business. I see this as useful insight into the stages of a business transformation programme particularly during the stages of vulnerability.

The instar steps are a complete metamorphosis of the chemical structure of the larvae to the eventual butterfly. The actual protein strands re-orientate. How many businesses would be prepared to make such a fundamental change to their business by restructuring at a molecular level?

Hawk Moth

Metamorphosis is the transformation from one state to the next such that very little of the previous state is recognisable in the final state. The butterfly model and the similar hawk moth model are used as the basis of the Life stages business biomimetic model (see page 81)

Crabs

In order to grow, crabs go through a process called ecdysis or moulting (Campbell and Reece 2005). The common shore crab *Carcinus maenas* goes through about eighteen moults in its four-year life. A hormone called ecdysone triggers a series of events. At one level, the crab increases the amount of water pressure raising the turgor pressure within the shell. At the same time, the shell weakens. Underneath the shell, the crab has already created the new shell although it is soft and wrinkled which is rather like wearing a large jacket underneath a smaller one. Once the pressure is high enough the soft crab bursts out of the shell leaving a carapace and a separate lower crab shell with the legs intact. To prepare for 'launch' the claw muscles weaken so that they can be pulled out of the old shell and essential minerals are recycled by short-term storage in the stomach lining. This demonstrates that the crab is temporarily vulnerable before making the change. The old shell is partially dissolved to recycle the components and to make it thinner and more flexible (easier to shed). (Crothers and Crothers 1983) The new soft crab takes two weeks to remineralise the shell and is susceptible to predation at this stage. On average, the new crab is about 30% bigger. It is believed that the trigger for ecdysis is a combination of received

internal and external stimuli.(Vines and Rees 1972). Ecdysis is used later to develop the Past Casting Model (see page 79)

Cricket

Like the crab, crickets follow the same process of splitting out from the exoskeleton. This process is called ecdysis and is common amongst all animals that have exoskeletons

Cockroach

A specific mention is made of the cockroach in terms of ecdysis. In its early post ecdysial state the cockroach lacks pigment and appears white. The cockroach, cricket and crab all exhibit ecdysis the basis of the Past Casting model (see page 79)

Reproduction

Plant physiology of reproduction.

Various methods of dispersal exist in the form of seeds, spores or fruits. They form a number of functions. They contain the plant DNA and a source of nutrition to allow growth once the environmental conditions are suitable. They provide a vehicle to disperse the DNA allowing the plant to ‘expand’ and are an investment for the future. Seeds are dispersed in a number of ways including wind dispersal (dandelion- *Taraxacum*), animals where the seed or burr attaches itself to the coat of the animal, ingestion of the seed in the form of a fruit by an animal or bird which is then excreted at a different location. Water allows dispersion of palms such as the coconut- *Cocos nucifera*. The thick fibrous walls of the coconut mean that there are air pockets allowing the ‘fruit’ to float away from the parent plant. The study of plant reproduction provided the inspiration for the Alternation of Generation model (see page 76)

Mistletoe

It relies on the structure provided by trees that it uses as a support from which to release its seeds. In the initial analysis of biological systems, Mistletoe was seen as a possible candidate for further analysis. It was later shown to be a core biological system (see page 145).

Bees

Bees live in a 'police' state (Whitfield 2002) eating eggs that have not been laid by the queen. (*Apis* sp). Haplodiploidy: In Hymenoptera, females have two sets of chromosomes and males only one (they come from unfertilised eggs). The coefficient of relatedness means that females are better, genetically speaking, looking after their sisters than their daughters. This encourages them not to lay eggs. Those that do are often quickly eaten. The overarching principle is survival of the whole which outweighs the survival of the individual.

Anemones

Anemones are adept at cloning and one individual can create a whole colony. *A. elegantissima* is a master at this splitting into two often in response to a predator attack by *Aeolidia papillosa*. (Harris and Howe 1979) The relationship between these two species is complex and could be used to develop a model as to how a business could protect its market position then, when required expand, competing with similar businesses using the competition of the competitor to create competitive advantage. When considered with the flea beetle system discussed in the next section this formed the basis of the Poison adaptor model (see page 75)

Excretion

Belladonna flea beetle – Epitrix atropae Foundras

The Belladonna Flea Beetle lives on the leaves of the Belladonna plant. This plant contains the neurotoxin atropine, which is why it is toxic to many other species. As a first level of defence, the atropine rich environment acts as a deterrent to competitors thus the ability to survive in this toxic environment provides an advantage to the beetle. Whilst the detailed biochemistry is not fully understood it is believed that the atropine is absorbed quickly by the beetle and deposited into fatty tissue (Narberhaus, Theuring et al. 2003). It is also thought that the atropine is also secreted onto the exoskeleton. Whatever the mechanism is, the beetle is then unappetising to predators.

Flea beetles are also attracted to plants that emit volatile organic compounds. The release of volatile organic compounds (VOC's) increases predation and could lead to a reduction in competition for the herbivore. (Halitschke, Stenberg et al. 2008)

Common Grey Sea Slug – Aeolidia papillosa

This sea slug is a predator on the anemone *Anthopleura elegantissima*. During the attack and alarm pheromone anthopleurine is released. (Harris and Howe 1979) This pheromone is acquired by the *Aeolidia* and has been found in the tissues up to five days later. Other Anemones exposed to the anthopleurine then retract their most vulnerable 'parts' typically the tentacles and oral disk (Harris and Howe 1978). The predator then effectively 'warns' other anemones that they are likely to attack. The sea slug utilizes the toxic environment by breaking off the toxin containing tips of the sea anemone and ingesting them. The tips then pass undigested through the slug and are secreted on the 'tail'. Providing more evidence for the development of the Poison Adaptor model (see page 75)

Clown fish and sea anemone

This is a good example of where one species works alongside the other. It is believed that the clown fish prevent undigested food affecting the sea anemone whilst the sugar based mucus coating of the fish protects it from the sting organelles. In turn, the clown fish is protected from predators by the anemone's stings. It is possible that the faeces from the fish provide a food source for the anemone. Further developing the use of both symbiotic relationships and chemicals as a defence mechanism.

Nutrition

Ectomycorrhizae – mainly Basidiomycota

Associated with the root structure of 90% of plants in the UK *Mycorrhizae* are responsible for the vast majority of plant life. They are a fungus that provide phosphates to the plant and get sugars in return.

Ants

Ants are experts in recycling. 11% of the leaf cutting ants, *Atta colomica* are involved in waste management. They are divided into waste heap managers and waste transporters. There does not seem to be switching between the tasks. The heap is situated downhill to avoid run off when it rains. (Hart and Ratnieks 2002). Other species also exhibit rule-based behaviours and this could be useful in understanding business relationships and activities. Examples include schools of fish, swarms of insects and flocks of birds. Whilst the ant biology was not specifically used in the

development of the biomimetic models, the relationship between control and chemicals was a key part of the thinking behind a number of the models.

Interrelationships

Having looked at the biological systems of a range of individual species the next logical step was to review the interrelatedness to see how a selection of species did or did not work together. Reflecting on the species reviewed showed that in all cases there was a relationship with at least one other species. Partnerships at some level seem to be critical.

Symbiosis in this thesis is used to describe the range of relationships that exists between organisms. It is used in the biological sense in that it covers all relationships and not in the lay sense which means a win-win relationship. At one end of the spectrum, commensalism is where two organisms directly benefit from their relationship and at the other is parasitism where one organism suffers or dies because of the relationship. Antibiosis goes one-step further and creates an environment where no other organism can survive or prosper.

A good example of two species living together to benefit both is Lichens. Fungi and algae or cyanobacterium – mostly *Ascomycota* combine to provide a new organism (the lichen). There is a mutually beneficial relationship sharing carbohydrate production and consuming excess nitrates. (Chambers, Morris et al. 1976)

Parasites in general cover a wide range of relationships. In all cases, the host suffers although the impact is everything from death to minor. What is important is the way in which the parasite takes advantage of the host. Parasites adopt a number of strategies to invade hosts then evade host defence mechanisms. In the human, parasites that invade the gastrointestinal tract, lungs and genito-urinary tract are still on the outside of the body and two examples of surface based parasites are *Neisseria gonorrhoeae* and *Helicobacter pylori*. The first survives in the mucus membranes of the genito-urinary tract by periodically changing a surface protein called pilin. This means that the epitopes that the immune system recognises and has already created antibodies for, have disappeared. While new antibodies are created the bacterium continues to survive. (Kimball 2004) *H. pylori* works in a different way. It neutralises the stomach's acidity by converting urea into ammonia. To gain access into the cells *H. pylori* then secretes a protein that weakens the seal between epithelial cells. This bacterium is the main cause of stomach ulcers.

Other techniques used to invade the cells include using the existing receptor transport systems, binding to receptor molecules in receptor-mediated endocytosis (they are sucked into the cells) and changing the surface proteins (as in *Mycobacterium tuberculosis*) so that they are not phagocytised by the macrophages. *Salmonella enterica*, once engulfed secretes a protein that inhibits the lysis of the bacterial cell. It ‘hitches a ride’ inside the cells whose role is to destroy (phagocytise) the pathogen.

Parasites that are blood based also change their chemical signature by creating new surface proteins. This way antibodies no longer recognise them so the detect and attack approach of the immune system is extended while more limited-use antibodies are created. The timing in *Trypanosoma brucei*, or sleeping sickness, is such that the number of protozoans in the blood rises and falls indefinitely. The malaria parasite *Plasmodium falciparum* creates a protein that causes the red blood cells to stick to the walls of blood vessels. This way they avoid being destroyed by the spleen. Like other parasites, the *Plasmodium* periodically changes the surface proteins to avoid antibody detection. (Kimball 2004)

Viruses, which are all intracellular parasites, create decoys for the cell surface receptors. They mimic the ligands the cells expect to engulf and as a result the viruses are taken inside the cells by the cells own mechanisms. Other countermeasures to avoid detection include lying dormant for long periods; *Herpes simplex* is a good example of this.

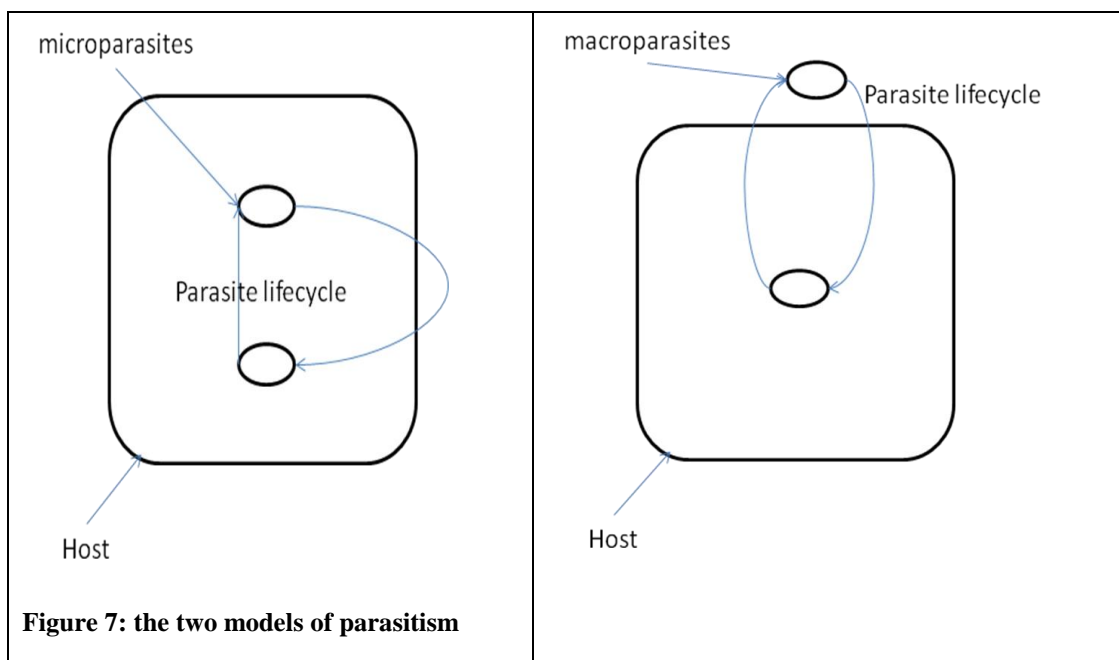
This is similar behaviour to that exhibited by the FMCG industries (fast moving consumer goods) they need to continually create new products for the supermarket channel so that the margin is not gradually eroded. Further parallels can be seen when comparing the sale of goods to multiple retailers and the cross species activity of certain viruses.

The key rule for all parasites is that they must leave the host and have moved onto another host before the host either dies or creates an effective barrier to the parasite. There are a number of ‘hit and run’ parasites such as influenza that often leave behind a host that is immune to subsequent infections. There are also examples of host behaviour modification that improves the propensity for the parasites survival. These examples include flukes which cause periwinkles to move closer to the surface so that

they can be caught by seagulls (the alternate host) and *Toxoplasma gondii* an intestinal parasite in cats. The alternate host is the rat and the parasite reduces the rat's fear of cats, increasing its likelihood of predation and the subsequent completion of the *Toxoplasmodia*'s parasitic cycle.

Plants also have symbiotic relationships. The most common is that with *Mycorrhizae* fungi where it has been shown that in poor conditions the fungus increases the plant's survivability(Tennessee 2004) The plants benefit from a more efficient uptake of phosphorous(Kimball 2004). *Ascomycetes* are common fungi. They include those that grow as truffles (symbiotic relationship with trees, usually oaks); *Saccharomyces* sp have, as their fungal partner, an *Ascomycete* fungus. The relationship is, in the main, mutualistic. It is estimated that about 14,000 species of fungi form lichens.(Kimball 2004) The role of parasitic plants has also shown to have an impact on the ecology of the host. Plants with parasitic plants often have restricted growth and where normally they would be in balance with other species the presence of a parasite enables other species to dominate the ecosystem. (Press and Gurney 2003)

Parasites can be considered to be microparasites such as bacteria, viruses or fungi that replicate directly in the host probably due to their small size. Macroparasites tend to have only part of their reproductive cycle inside the host. (Dobson and Carper 1992) Macroparasites tend to be long lived in comparison. **Error! Reference source not found.**shows the different pathways for parasites. Microparasites are internal to the host and macroparasites start externally then spend part of their cycle inside the host.



Alarm calls in plants

Plants use volatile organic compounds (VOC's) to attract predators (Harris and Howe 1978) when suspect to attack by herbivores. Examples include the creation of green leaf volatiles (cis-a-bergamotene) wild tobacco plant *Nicotiana attenuata* in response to tobacco hornworm (*Manduca sexta*) and the subsequent increased attraction by generalist predator *Geocoris pallens*, see **Error! Reference source not found..** The increased VOC's also seem to attract the flea beetle by *Epitrix hirtipennis* which may benefit from the reduced competition.(Halitschke, Stenberg et al. 2008)

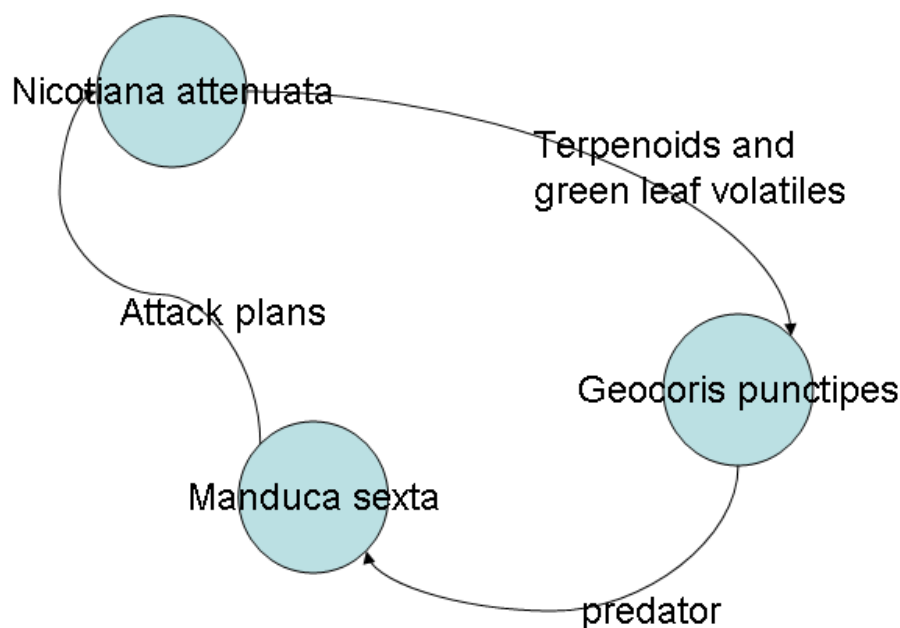


Figure 8: alarm signals, the release of volatile organic compounds (VOCs) to attract herbivore predators after (Halitschke, Stenberg et al. 2008)

The use of VOCs to attract predators could be described as a type of security. An analogy in business could be one of outsourcing i.e. using an external resource to complete a process.

Evolution

Whilst this review has covered a small number of biological systems, it would not be complete without considering evolution that is one of the key theories of biology. Lamarck's view of evolution is that the environment created the adaptations in the animal. The giraffe grew its long neck because food was only accessible above a certain height (Lamarck 1809). This is counter to the view held by Darwin that the

animal used a naturally selected adaptation to access new food sources(Darwin 1859). He suggests that whilst the habitat may have had some effect it cannot be used to explain the differences in horses from a dray to a racehorse unless one accepts that man has created this adaptation through selection (p25). In this way, evolution can be a useful source of inspiration and the argument applied equally. When considering a business venture the two views on evolution when applied challenge whether the capability of the business is changing in line with the environment (or being left behind) or whether all the emerging capability of the business is being best utilised. The argument can be seen clearly when applied to giraffes. Fossil evidence (Roberts 1977) demonstrates that the ancestors of the giraffe had shorter necks. Lamarck suggests that they kept stretching for the better leaves and managed to pass this longer neck onto their offspring. Darwin's view is that spontaneously longer necked giraffes appeared and by the process of natural selection, they survived.

There is no direct evidence to support Lamarck's view, yet it produces a contrast, which can be applied to a business. It is either that businesses today follow Lamarck's approach which is 'stretching' the necks of giraffes to reach the better leaves or Darwin's approach is taken which would suggest a random ability to reach the higher leaves. If this was the case then the skills and abilities needed in a business could actually appear anywhere. It is sometimes the case that much time is spent by a business looking for the spontaneous ability to perform versus the neck stretching development approach. Evolution does not equal efficiency so there is a challenge as to whether the random selection of the business is more suited to the current environment, which would be the Darwinian view or whether the current selection changes to fit the new environment, which is the Lamarckian view. Darwin's approach makes sense if there is reproduction involved and is the currently accepted version.

Evolution tends to be considered as a long term change although several breeds of sheep and cattle have been modified by a manmade intervention into the selection of certain characteristics, in a single lifetime(Darwin 1859). This shows that selection is possible in a much shorter timeframe and is therefore a possible source of biomimetic inspiration. One possible application of selection and evolution is in the creation and implementation of mergers and acquisitions. However, unlike mergers and acquisitions, breeders tend to select from the same sub species rather than cross breed.

Breeders and horticulturalists do not encourage selection by picking the most likely to succeed. They are more interested in weeding out the weaker specimens to stop them propagating so that they end up giving the strongest stock room to grow. A business

parallel could be the mechanism of redundancy where underperforming roles and the people who are in them are weeded out. Although keeping control of the finances are an important component of the business and redundancy is often essential to business viability, in some cases good ‘stock’ is lost and weaker specimens survive to ‘propagate’ therefore reducing the long term success of the business. This could be an interesting area to build into a biomimetic model.

A good example of how evolution has provided different solutions for the same problem is sticking things together. Figure 9 shows a range of organisms and their types of stickiness.

Glue

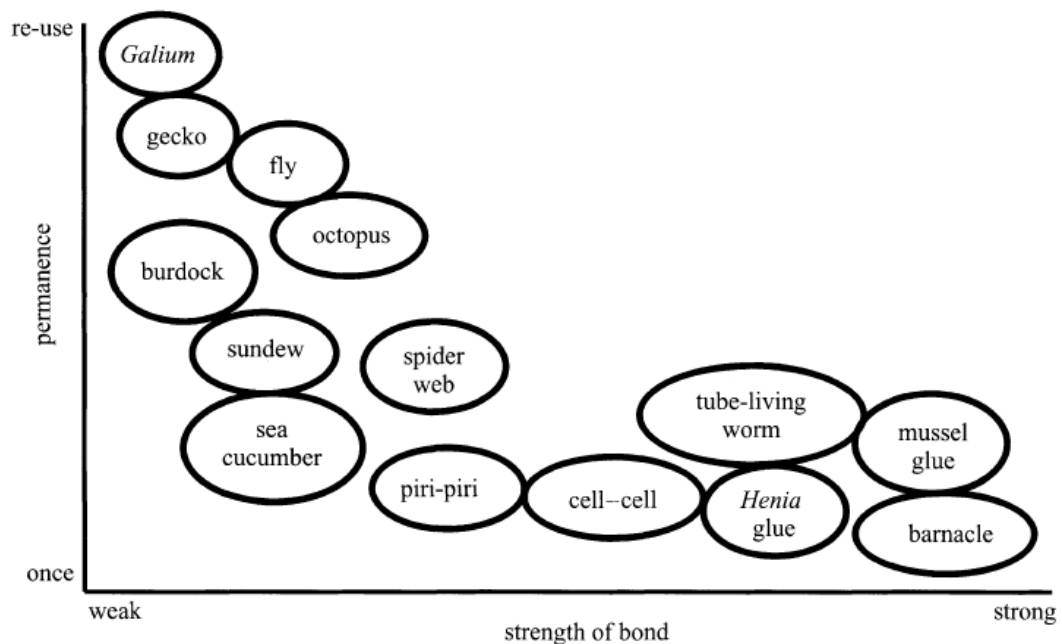


Figure 9: different types of glue from Biomimetic Modeling, Vincent 2003

Figure 9 shows the range of biological solutions to the problem of bonding. There is not a one size fits all and this is important to bear this in mind when looking to biology for answers. It is not enough to merely ask for a solution that sticks things together. The work by Vincent highlights two other dimensions to consider, permanence and strength. The solution is then dependent on a full and detailed understanding of the problem. Another example of where nature solves problems differently is shown in the work by Vincent analysing the use of space, structure, substance, time, information and energy. (Vincent, Bogatyrev et al. 2006) Here the difference between the profiles for humans and other species is compared. It highlights the vast difference in the use of energy usage; man uses more energy to solve problems of similar size. This facet of multi-solutions is a recurring theme in biological systems and seems to run counter-intuitively to the traditional business approach, which is looking for an answer.

How nature operates

Studies by ecologists have been enshrined into a set of principles (Benyus 1997). Table 7 provides a useful checklist for developing an understanding of how nature operates. Taking this checklist and applying it to a business environment is a good starting point for considering the possible role of biomimetics.

Principles from nature
• Nature runs on sunlight
• Nature uses only the energy it needs⁴
• Nature fits form to function
• Nature recycles everything
• Nature rewards cooperation
• Nature banks on diversity
• Nature demands local expertise
• Nature curbs excesses from within
• Nature taps the power of limits

Table 7: Principles of nature from Benyus 1997

The study of biomimetics is driven by two aspects; the first is from the basic principles of biology where biological systems are studied and the potential application of these studies. The other is from the engineering aspect where problems are presented and suitable biological systems are then examined. This can be challenging particularly when a complete knowledge of all biological systems does not exist. There are currently a number of attempts to link biological functionality to engineering. (Benyus 1997; Mann 2001; Vincent, Bogatyreva et al. 2005)

⁴ Where need is that required to survive and reproduce

Biomimetics – examples

There are a growing number of examples whereby lessons from nature have been applied to producing a new solution.(Vincent, Bogatyreva et al. 2006) Examples include

- Velcro from the dog burr
- Self cleaning paint from the Lotus plant
- Antireflective surfaces based on insect eyes
- Car design from fish (Mercedes Bionic Car)
- Dry adhesive tape from reptiles
- Ploughs based on soil moving animals

However, there does not seem to be any examples of how biomimetics has been used to improve a business, design a process improvement or manage a change

Design

Nature takes a low budget approach to design (Ball 2001). The evolution of design in nature achieves a ‘good enough’ solution rather than the optimum.(Vincent, Bogatyrev et al. 2006) There appears to be a focus on gaining the maximum return for minimal outlay. Nature appears to manage risk by seeking several solutions simultaneously as could be seen from the glue example earlier. Nature also works to a different set of rules allowing insects, for example, to take off backwards, land upside down and in the case of the bee, able to use the energy in vortices created by the previous wing stroke to support the next stroke. In insects, the wing is not connected to the flight muscle. The muscles move the cuticle instead to get the maximum movement from a small strain.(Dickinson and Tu 1997). This is counter intuitive in that the affect is achieved by acting on another part of the system. The approach could be applied in a business context where more consideration was put into the system surrounding a business problem and options were examined where the solution was implemented in another part of the business.

The following examples from the application of biomimetics to design highlight the wide range of solutions available to the designer. The purpose of reviewing these examples is to show the diversity of inspiration that is achievable by using nature.

Biology and Engineering

The bionic car is a well-known example designed by Mercedes. Starting with the box fish (family, *Ostraciidae*) the combined team of engineers and biologist have developed a concept car that has a coefficient of drag (CD) of 0.19 because of

streamlining concepts taken from the box fish (figure 11). Conventional approaches in engineering would have not started with a box as the design parameters for automotive development (see Table 8). It appears that biologists have the answer and engineers have the question. (Vincent 1997). This low CD is almost half of the current popular makes are shown in table 8 for comparison.

Vehicle Type	Drag Coefficient - C_d
Fiat Uno ES	0.33 - 0.34
Peugeot 205 GL	0.35 - 0.37
Renault 5 GTL	0.35 - 0.36
Honda Civic 1.2	0.37 - 0.39
Opel Corsa TR	0.38 - 0.39
VW Polo Coupe	0.39 - 0.40
Mitsu Colt 1200 GL	0.39 - 0.42
Ford Fiesta	0.40 - 0.41
Fiat Panda	0.40 - 0.42
VW Beetle	0.48 - 0.49
Citroen 2 CV	0.51 - 0.52

Table 8: CD for a range of popular cars⁵

⁵ From <http://www.mayfco.com/dragcd~1.htm> accessed 21st June 2010



Figure 10: Boxfish courtesy of www.daimler.com 2008



Figure 11: Bionic Car courtesy of www.daimler.com 2008

Technology

Modern analytical devices are looking to optimise the efficiency with the minimum of energy consumption (Ramirez-Garcia and Diamond 2006). This is perhaps a convenient way to suggest that nature has spent ‘billions of years’ perfecting solutions to problems and that this approach can be applied to any subject that needs a boost in terms of focusing on efficiency and low energy usage. It avoids the discussion about evolution and ignores the external environment. This type of thinking “would nature have the answer to these problems?” implies that it will be a potential source of solutions.

Robots

Robots designed as early as 1949 were able to mimic a simple nervous system by being able to detect and navigate towards a light source. (Holland 2003). This has led to mimicking the motion of insects, which has led to the development of robots that can move in environments that are more complex. An example of this comes from the Hochschule in Magdeberg (Figure 12), Germany where they have developed a concept for a machine for building demolition without the need for heavy-duty cranes and demolition equipment.



Figure 12: building demolition concept from Hochschule

Nature has solved the approach to jumping in different ways. ‘Pause and leap’ is the method found in locusts, other insects and frogs where there is a rest stage between leaps to get the energy back. Kangaroos recapture the energy in the jump to keep going which requires specific control. Fleas store energy in small muscle ‘ratcheting’ the energy into a tendon that is hooked over a hook. In dogs, the energy is created in the tendon by compression where the dog crouches before springing. The jump is then augmented with the muscles. Jumping robots (Armour, Paskins et al. 2007) suggest that jumping could be a useful metaphor for businesses. The challenges in designing a

jumping robot that can move across rough terrain could be useful in thinking about how businesses transverse similarly rough terrain. Whilst the final robot solution failed to achieve its intended goal of multi-functionality the use of this as an extension to the nature analogy is still relevant. One principle to consider is the storage of energy prior to a jump and how this might be relevant to business. Whilst this thesis is about the application of biological systems to business and not biomimetic ideas, the logical of the section above provides insight for the way of thinking about the potential application.

Structure

Structure provides another insight into the way nature solves problems. One example would be the very fine nano-sized hairs on the foot of the Gecko. These hairs are believed to interact with the surface using van der Waals' forces.(Nobel Institute 1967; Bar-Cohen 2006; van der Wal 2006; DTI 2007). What this highlights is the need to carry out the biological observations at a very detailed level. In researching the business applications of biology most of the work was carried out at a superficial level of biology. Work at Max Planck Institute in Gölml, Germany has led to discussions on the fly foot work and how at the nano-scale there was also a similar link to van der Waals' forces. Both the gecko and the fly work are looking to develop non-sticky adhesives.

Lotus effect

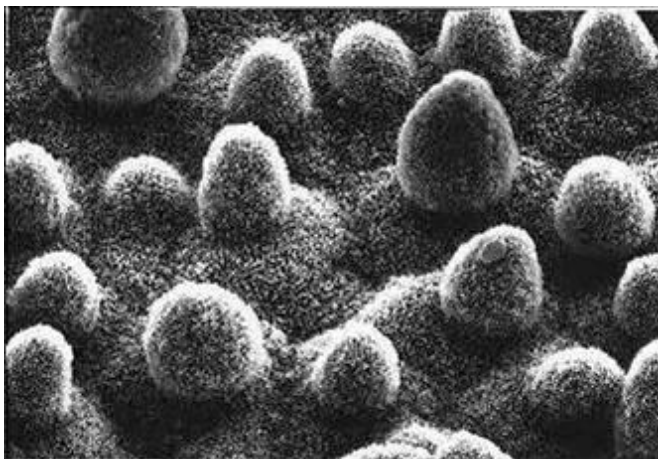


Figure 13: The surface of the Lotus Leaf, <http://www.botanik.uni-bonn.de/system/bionics.htm> - accessed January 2007

The hydrophobic effects observed on the leaf of the Indian lotus flower (**Error! Reference source not found.**) have been reproduced by structuring the surface of polymers with different sizes of wax particles. Counter to expected results it is a rough surface that provided the hydrophobicity. Particles have a low adhesion to the surface. Therefore, that water rolls off the surface easily taking the particles with it. Work done on Teflon Colloids at the University of Cambridge(DTI 2007) has shown that the contact angle is a key determinant in the ability to create a hydrophobic surface. So rough is better than smooth! The contact angle of 160° can be achieved using existing manufacturing methods(van der Wal 2006). Lotusan⁶ is a paint developed in Germany using this principle to create a self-cleaning surface (once the paint has dried). (Vincent and Mann 2002). Other applications at ITV Denkendorf show the same principles applied to cloth used in awnings and water repellent materials.

Microfluidics

Microfluidics is the manipulation and analysis of fluids in a sub-millimetre environment with a typical volume of 1mm^3 . The fluids are typically complex; blood, saliva, urine etc. The key potential application is in medical diagnostics where it would be possible to put the diagnostic test onto something the size of a credit card. Work being done by Philips and the University of Utrecht is focused on the development of biosensor devices (Figure 14). Using Paramecium (which is a Protozoan) as the biomimetic inspiration, they have developed a mechanism to move and mix fluids based on the motion of cilia. By creating artificial cilia using MEMS (*Micro-Electro-Mechanical Systems*) Philips has created small polymer micro-actuators which can respond to light, temperature, liquid as well as electronic and magnetic fields.

⁶ <http://www.stocorp.com/allweb.nsf/lotusanpage>

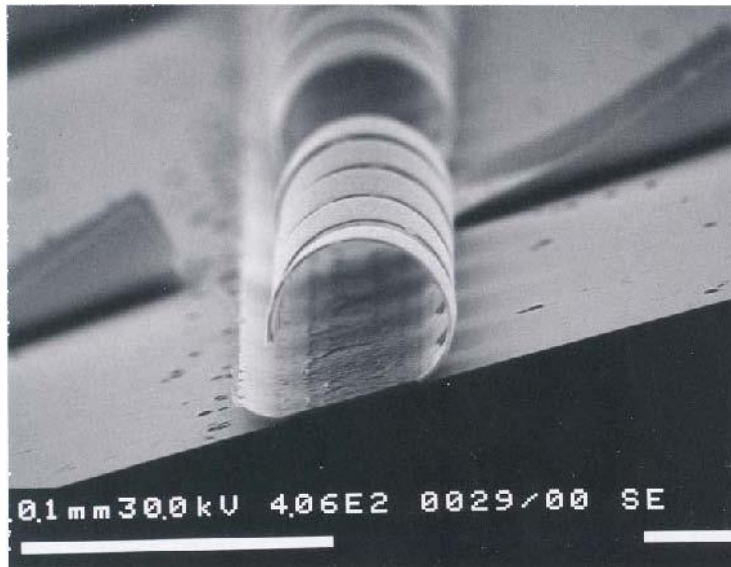


Figure 14: Microfluidic actuators based on the cilia of *Paramecium* - courtesy of Philips 2007

The man machine interface

Delft University of Technology in the Netherlands is a leading exponent of the interface between man and machines. Using observed natural intelligence and building on the experience with artificial intelligence is used to inform the specific areas of trust, negotiation and co-operation in social networks. With a focus on the development of software, a number of interesting results have been produced including an intelligent desktop negotiator that can negotiate faster and achieve a better outcome than humans achieve. Ant like computing, embedded embodies cognition – it is the whole body that counts not just the brain. At the highest aggregation level, the ants find the shortest path. A practical application of this type of work is in the creation of a simulation for food supply chains. (Tykhonov, Jonker et al. 2008)

Having examined a number of biomimetic examples, I now want to widen the discussion to look at the broader field of biomimetics and how that might be relevant to business.

Linking Biology and engineering

Based on the Russian method for inventive problem solving, TRIZ, there are suggestions that it is possible to create a systematic technology transfer from biology to engineering. The TRIZ framework offers an objective method for assessing problems. By adding in biological systems based on their functionality a richer set of

problem, solving solutions would exist. Of particular relevance is the claim that the TRIZ framework would make it easier to identify areas in biology that are likely to provide information about specific problems. Almost suggesting the possibility that, given time, it will be possible to automate the search for functionality matches building on the TRIZ concept of 'self generating'. This approach was developed in 2005 when (Vincent, Bogatyreva et al. 2005) developed a biological database for TRIZ. This created a key challenge in translating the levels of functionality found in nature into engineering chunks. It provides a logical and accessible argument for the cataloguing of nature for engineers. It also raises the question whether a constraint is being applied by looking only at engineering applications. Organisms are subject to constraints, history, physics laws (Kaplan 2003). Later I will explore the wider application in business which encompasses engineering approaches and show the role of constraint as a positive element in developing business ideas. The work recognised that the approach would result in a loss of detail as functions were "glossed over".

The system operator used in developing the biological database provides a useful way of putting into context the super and sub systems of the area under examination. This aligns well with current thinking on business strategy which links the global strategy with the local strategy and then the departmental strategy. (Boojihawon and Segal-Horn 2006). Alternatively the process from biology to engineering could be verified by manufacture (Vincent 2003) which potentially answers his hypothesis about the possibility of transfer of 'technology' from nature to engineering (Vincent and Mann 2002) Having decided to focus on biomimetics the real challenge was reviewing the three disciplines that seemed to intersect at the term biomimetics; engineering, biology and management science.

The scope of the thesis covers the identification of business issues, the development of a number of new frameworks and then the comparison with traditional management models. (Segal-Horn 2004; Grant 2008) In addition it will look at the acceptance and response to the concepts of biomimetics in business. As there are a significant number of variables in the development and implementation of business strategy the thesis will focus on the generation of ideas as the precursor to strategy development. This assumes that ideas will lead to innovative solutions.

Architectural examples

The Roof of Crystal Palace, London.

This was designed by the landscape designer, Joseph Paxton. He based the design on the water lily, *Victoria amazonica*. Paxton copied the rib structure found underneath

the leaves to construct a light but strong steel and glass roof. Although this is disputed due to a lack of apparent evidence. (Vincent 2009)

The Eiffel Tower, Paris

This is thought to be based on the riblets of bone found inside the human thighbone. Like the thighbone the Eiffel tower supports an offset weight. Karl Cullman discovered these riblets or trabeculae when visiting Hermann von Meyer an anatomist. Again there are questions being raised as to the authenticity of this understanding (Vincent 2009).

Earthquake proof buildings

These buildings have been constructed using honeycomb technology taking advantage of the honeycombs property to absorb vibrations. The ‘waggle-dance’ of the bee causes intense vibrations in the hive, which if scaled to human size would measure on the Richter scale (Tautz and Rohrseitz 1998). This technique has also been considered to be of use as a tool to predict where existing buildings would fail due to earthquake vibration. The approach is also being used in aircraft design as it also provides a light but strong structure. Other examples that have been looked at include sound and vibration dampening in the foundations of high speed trains. (Takemiya 2004)



Figure 15: Millennium Bridge in Gateshead, UK showing the eyelid design

The current application of biomimetics is best demonstrated in engineering and architecture. There are examples such as the Millennium Bridge (**Error! Reference source not found.**) in Newcastle, representing a human eyelid in the way it opens and closes and the roof of Stuttgart Airport (**Error! Reference source not found.**) where the functionality of engineering performance has been blended with the design.



Figure 16: Tree like structure at Stuttgart Airport courtesy of Matthias Gester P&G 2007

Getting to the hypothesis

Management needs models or frameworks to manage. The frameworks are needed for analysis, diagnosis, planning and implementation. If the biomimetics approach is to work then it will need to satisfy these requirements. The change kaleidoscope (Balogun and Hope Hailey 2008) is a good example of such a framework and sets a standard by which future models must aspire. Strategy uses a number of models and concepts much in the same way as there are a range of biological systems that combine to create the natural world. Having identified the functionality from a biological system the challenge for an engineer is how to do it (Vincent 1997). The same problem also applies to the strategist. There is a need to provide a way of translating between the biological solution and the business issue.

The hypothesis for the thesis is that biomimetics can be applied to a business to improve the business performance. Specifically to compare biomimetic with the traditional business models and to show that they produced ideas had a better impact on a set of key performance indicators. The critical measure of success for the hypothesis was that the biomimetic models produced ideas that were better than or as good as those produced by the traditional management models. A further measure of

success is that these generated ideas would be implemented by the business as part of the strategy to improve the business performance.

This led to the objectives being defined (see page 15) it was believed that using this technique would invigorate strategy management thinking and provide an opportunity for the team to see challenges from a different perspective whilst increasing idea generation. This is important from a business point of view as it provides a new paradigm of thinking and therefore solutions. Thus creating a new focus for competitive advantage.

Chapter 4 Building the biomimetic models

Having discussed current management science and looked at how biological science approaches many similar issues, it was appropriate to bring the sciences together to consider how biomimetic models could be developed to satisfy strategy demands. The biomimetics linked with engineering and architecture offer useful examples of how nature has been adapted to fulfil man made needs.

At this early stage of the development of business biomimetic models, nature and business can be aligned in the Table 9. This table takes the cell structure discussed on page 39 and shows how business has adopted a similar hierarchical approach. The right hand column takes a parallel approach to show how this biological thinking might be applied using biomimetics to create a business biomimetic structure.

Life	Business today	Biology and business (business biomimetics)
Cells	Resource	Data
Tissue	Capability	Insight
Organ	Function	Evolution
Organism	Business	Internal Environment
Ecosystem	Market	External Environment

Table 9: Alignment of biological and business structure

Biomimetic models

The identified business issues were used as the starting point to develop the business biomimetic models. **Error! Reference source not found.** Shows the process starting with the business issues then reviewing a range of biological systems. Biological systems were then identified based on broad similarities between the business issues and the biological system. Not all of the biological systems introduced in *Chapter 3 How biology might have the answer* were used explicitly in the development of the biomimetic models. The identified systems were then consolidated into similar

systems and the consolidation used as the basis for developing a biomimetic model. To validate the process the biomimetic models were then checked against the original business issue to see if there was a relationship. It is recognised that this is not a tightly controlled method and that the approach relies on the biological expertise of the author to identify systems that merited further scrutiny. The approach was also limited in the scope and scale of biological systems that could be examined.

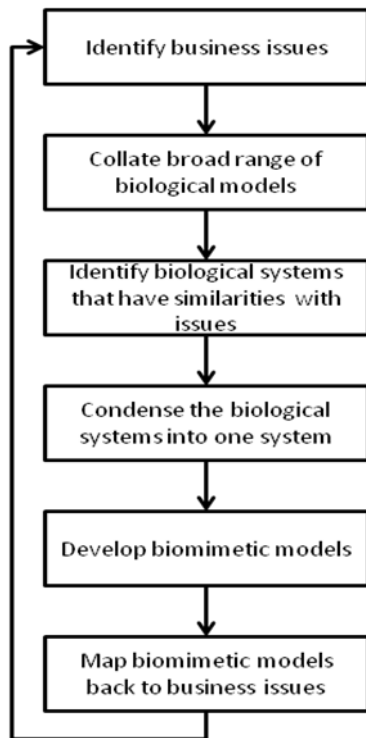


Figure 17: Process used to develop biomimetic models based on current business issues

Table 10 shows the short list of biological systems identified and the reason why they show potential for a biomimetic application. Many of the examples of biological systems used have been deliberately well known and easily identified such as bird flocking and insect swarming. In using these particular systems, the user of the biomimetic model will be familiar with these concepts and therefore readily grasp them thus avoiding being diverted by ‘the weird and wonderful ‘of the natural world.

Identified	Potential link to the business issues
MRS GREN (p41)	Checklist for life and fitness
Ectomycorrhizae – mainly <i>Basilomycota</i> (p 47)	Providing a two way delivery of essential benefits without which both parties would suffer
Lichens fungi and algae or cyanobacterium – mostly Ascomycota (p 48)	Working so closely together that you appear as one
Mistletoe and other fungi that climb trees to release spores (p 45)	Using others to gain advantage without disadvantaging them
Parasites (p 48)	Gaining at the expense of others or using others to gain advantage without regard to their fate
Clown fish and sea anemone (p 47)	Working within the protection of others
Bird flocking (p 41)	Working together. Following rules. Providing safety in numbers
Fish schooling (p 42)	Working together. Following rules. Providing safety in numbers
Insect swarms (p 42)	Team behaviour
Belladonna flea beetle – <i>Epitrix atropae</i> Foundras (p 46)	Working in hostile environments. Creating competitive advantage from adversity
Common Grey Sea Slug – <i>Aeolidia papillosa</i> (p 47)	Working in hostile environments. Creating competitive advantage from adversity
Plant physiology of reproduction. Spores, gametes and zygotes the value of seeds (p 45)	Routes to market and future proofing
The life cycle of plasmodium which has two different hosts (p 42)	Ability to exploit two unrelated markets
<i>Carcinus maenas</i> – common shore crab (p 44)	Growth when constraints exist
Cricket (p 45)	Growth when constraints exist
Cockroach (p 45)	Growth when constraints exist
Hawk Moth (p 44)	Changing to exploit different environments or as a way to grow

Table 10: Aligning biological systems with business problems – linking the business problems with the models

The biological systems and the reasons why they were chosen

The intention here is not to provide a detailed explanation of the biological systems but to highlight some of the areas of interest that the system exhibited. It is based on a

broad piece of analysis and not a thorough in-depth analysis of biology because the thrust of this thesis is how biological systems can be of use when applied to business strategy rather than merely looking at the biological systems.

Having identified the biological systems it is then possible to create business biomimetic models based on the similarities. The models were developed through a series of trial and error steps carried out with the aim of producing a robust biological model that could be used in a business context. The criteria for development are shown in Table 11.

Keep the biological model simple so that it is recognisable to a management audience
The biology needs to be 'explainable'.
The model needs to be represented in a PowerPoint slide as this appears to be the accepted means of communication in the management community
The model needs to be an analogy (not mimicry which would aid strategic thinking)
It needs to avoid controversy in the field of biology

Table 11: Model selection criteria

Using this as a basis for development the biological systems were consolidated into broad areas from which the final models were designed. Table 12 shows the consolidated biological systems and the business biomimetic models that were developed from the consolidation.

The models were then compared to the original business issue to validate the process which is also shown in Table 12. At this stage the models could be presented showing a direct relationship between the business issue, the biological system and the business biomimetic model which is shown in the same table therefore developing the idea of how the three areas could be brought together. It is worth noting that each model works across a spectrum of responses. An example would be Symbiosis, which is presented here to show collaborations and partnerships. These could be both positive and negative. Not all partnerships are necessarily mutualistic.

Business issue	Biological consolidation	Business biomimetic Model
Working across functions. Governance. Supply chain	Flocks, schools, swarms and shoals	Flocking (p71)
Joint ventures, collaborations, competition, co-operation	Symbiosis	Symbiosis (p73)
Growth and competition	Adapting to toxic environments	Poison Adaptors (p75)
Resources and capabilities		Alternative generations (p76)
Competition	Parasites	Two Host Parasites (p78)
Growth and sustainable competitive advantage	Ecdysis	Past Casting (p79)
Integrated Supply Chain	Ecosystems, structures of organisms	MRS GREN (p80)
Diversification and innovation	Life cycles	Life stages in two environments (p81)
Where value comes from in a business, customers	Some types of symbiosis	Symbiosis (p73)

Table 12: translating the business issue into the biomimetic model

An interesting challenge emerged during the development of the models. In the business environment, the term ‘customer’ is used prolifically to describe the recipient of products or services. However, in biology there does not seem to be a clear parallel. Whilst it could be argued that some commensal relationships mimic the customer-supplier relationship and possibly that, the food chain concept demonstrates a degree of ‘customer satisfaction’, the notion of customer in the business sense is elusive. It could be argued that the customer is the predator, or at least the next level in the food chain. This, however, assumes consumption of the ‘supplier’, which is not a sustainable business model although this could apply for a business that has a limited life span. Examples could include the products and services associated with a one-off music event or a business that is catering in a niche market such as is seen in the fashion industry. Taking the predator argument into customer service, customer satisfaction is the health of the predator population. This also ties back to the earlier biological model of flocking and schools where predators hunt as a group (Krebs and Davies 1993).

In developing the initial mapping of the business issue to the business biomimetic model two clear issues emerge. These can then been summarised into growth and working together and consolidating the business issues into key themes. Suitable biomimetic models for growth include poison adaptors, past casting alternative

generations and life stages in two environments. Working together including work within a team and working together as an organization can use models such as flocking, symbiosis, MRS GREN, or two hosted parasites.

This reflects the overall focus of most management teams where the two key drivers are growth and cost reduction. This and the analogy between cash in business and energy in nature will be explored later. Having identified the business issues and decided that the requirement was for a series of models the next step was to build these models using the identified biological systems.

Building the models

The biological consolidation was translated into a management model by asking the following seven questions. I developed these questions as a way to test the suitability for selection and as a validation step for the earlier criteria.

- What is the context of the system?
- How does the system operate in that context?
- What are the distinct features of the system?
- What are the benefits or results of the system in operation?
- What could be distilled as the key points of principle?
- Are there any immediate insights?
- What match exists to the business issues?

The business biomimetics models as used in the test case and the case studies are presented below.

Flocking

The flocking model highlights the integration and coordination between individuals of the same species (see page 41 for the biological systems used as a basis for this model). Good examples amongst birds include the starling (family *Sturnidae*), Canadian Geese (*Branta canadensis*) and swallows (family *Hirundinidae*). Some fish such as Sardines (family *Clupeidae*) exhibit similar behaviour as they swim in shoals. This interaction has a number of attributes such as protection from predators and as reproduction behaviour. In all the cases examined there appears to be leadership and decision-making happening without an obvious leader and a rigid infrastructure.

These examples of leadership and change are translated into rules and behaviours for businesses such that they could operate effectively without traditional leadership and management structures. The Flocking model then becomes a checklist model that is used as a set of principles:-

- ✓ Rules
- ✓ Patterns
- ✓ Programmed responses
- ✓ Groups
- ✓ Protection
- ✓ No leadership

Typically, management is structured hierarchically. Other vertical structures have been used to create a 'flatter' organization that reduces the different levels of management however; all these models still propose a definite leader (Mintzberg). This model has no vertical structure. It is based on the rules by which members of the organization operate together. Swarming behaviour in bees and flies has also been included in the design of the model after examining the latest computer modelling work on boids⁷ (Reynolds 2003). Whilst the behaviour of flocks and shoals works by each individual having a space relative to its neighbour, swarms work differently because individuals are trying to be in-between close pairs. The effect of this is to cause the swarm to bunch up tightly and therefore keep together. The different biological systems were condensed into a model that used behavioural rules.

The flocking model when applied to a customer service situation would work in the following way

- When a customer is seen, offer to help
- When a colleague has been with a customer for more than five minutes then offer to help
- When two colleagues have been with a customer for ten minutes then approach the customer and offer an alternative solution
- Review the customer request to determine whether the product or service needs changing

⁷ Computer simulation of a member of a group

The above approach which shows an example of how Flocking could be used and does not need a management structure. The same model can be used in a consulting environment where all consultants work to a set of rules designed to improve the client condition. This approach challenges the need for the consulting partner model and could potentially reduce the overall costs for clients. When combined with a robust training programme the flocking model allows organisations to operate with no management structure.

The flocking model is implemented by setting the high-level principles that govern the business or problem being addressed. These rules are encapsulated in a set of processes that are fully focused on delivering value for the customer of the process. The processes are used as the basis for training combined with the rules and is the outcome of working with the Flocking model.

Symbiosis

The biology behind symbiosis examined in Chapter 3 (see pages 42, 43, 45 and 47) highlighted a wide range of symbiotic relationships between organisms. Mutualism at one end of the organisms scale was where two species cooperated such that both species benefitted. Parasitism, at the other end of the scale, meant that one of the species died because of the relationship. The notable exception in symbiosis is antibiosis where one species makes it impossible for another species to survive. This has been included in the design of the Symbiosis model as it provides useful insight as to how organizations who take a complete self-interest and disconnect from the external environment may eventually suffer at their own hands because they have poisoned the market in which they are working.

The Symbiosis model (**Error! Reference source not found.**) is a three by three grid used to map the relationships between two organizations. They can be partner organizations, competitors or departments within the same organization. Each organization has its own axis. The initial plot is done by asking each organization what it believes the relationship with the other organisation to be. This is then plotted across the range of Mutualism through commensalism to Parasitism with a simple scoring mechanism of positive, neutral or negative. The question is asked from two perspectives. What do you get out of the relationship? In addition, what does the other organization get out of the relationship? This approach works best if the two organizations are asked separately then the two results plotted. The difference in the position of the two points is then the basis for an exploratory discussion.

- M – gaining for both
- C1 – gaining without impact
- P – gaining at another's loss
- C2 – taking away from others

		You		
		Gain	Null	Lose
others	Gain	M	C1	C2/P
	Null	C1	Neutral	
	Lose	C2/P		Competition

Figure 18: Symbiosis model used in cases

The next step is to ask the two organizations what the relationship should be based either on the past agreement or what the intended relationship needs to be based on the strategy for the future. Again, the difference is the basis for a discussion. The Symbiosis model is also used to map out a range of relationships with either customers or suppliers. If the initial plot puts all the relationships in the top left of the grid (mutual & mutual), then the grid is redrawn by zooming into that square and applying the grid again. This ‘zooming’ approach is continued until a manageable dispersion of the customers or suppliers is achieved. Typically run in a workshop situation, it is important to seek evidence to support the plot position.

The power of the Symbiosis models comes from highlighting the difference between what management thought or wanted the relationship to be and what it currently is. The model also works across a time period as it can show how the relationships have changed over time and what started as a mutual/mutual relationship has moved to a mutual/parasitic or parasitic/parasitic. Potentially both organizations are investing in what they believe to be a positive relationship when they are actually assisting in their mutual destruction. For example, two businesses could sign a contract to say that they will work in partnership to launch a new product to market (mutualism). After a period of time one of the partners gets more orders for other products because of this new product, the other partner is not affected (commensalism). Finally, the first partner changes the payment terms so that the second partner gets their share of the revenue later. This impact on the cash flow affects the marketing spend of the second

partner whose overall sales drop (parasitism). In this example, the first partner is unaware of the changing symbiosis that exists with their partner and is then surprised at the changes in behaviour.

Parasitism need not result in death of the partner although there are many examples from the business world where small suppliers have been squeezed out of the market due to the dominance and demands of one customer. At a more pragmatic level, it could be the simplest changes in terms and conditions of a supplier that has a significant impact on the cash flow of a customer. This could mean they can no longer work with that supplier. This 'changes over time' approach can help identify value-destroying behaviour and is a key benefit from the use of the model.

Poison Adaptor

The Poison Adaptor (Figure 19) model is based on the biological systems (see pages 43, 46 and 51) which have adapted a toxin in their environment so that they can survive where others would not and they have used the toxin as a way of protection from predation. This ensures that competition is stopped on two levels, competing for resources and competing for survival. The Poison Adaptor model structure makes two requests. What is currently toxic in your environment? In addition, how could you use that toxin as a competitive differentiator?

The starting point is to identify any areas in the current environment that consumes resources which when consumed do not result in value being added for the business. The response to legislation is a good example when organizations typically put in a mitigation strategy to cope with the ever-changing pressures. Other examples of how the Poison Adaptor model could be applied include changes in customer behaviour and changes in supply business terms or product quality. The change in banking and the pressure from customers on banks to remain open was solved using a Poison Adaptor approach. The 'toxin' in this case being the pressure from the customer to remain open for longer. By using the customer presence as the driver for the change, the solution was to install cash machines so the customer pressure now became the solution. In the early days of cash machines, this became a competitive advantage. As charges for making withdrawals are being introduced the cash machine solution framed as a Poison Adaptor approach, has become both a feature and benefit to the bank.

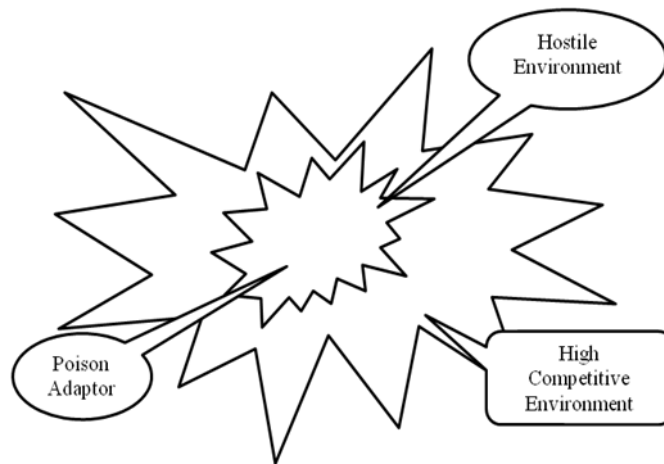


Figure 19: Poison Adaptor used in cases

The key to the success of the Poison Adaptor model is to improve the value generated from the use of resources that would otherwise be consumed without generating value. This approach can also be applied at a micro level within a department. An example of this is the problems associated with having small numbers of specialist staff that could be replaced with multi-skilled workers. The model will also work for those businesses that need to demonstrate compliance as it will facilitate a change of thinking from mitigation to value creation.

Alternation of generations

Based on reproduction (see page 45) this model (Figure 20) looks at how the genetic code is stored, combined and then released. This model is concerned with the longer-term issues and survival strategy. It also brings in diversity and growth in an attempt to survive. The analogy of the seed stage in this model is potentially closer aligned to developing a brand, product or intellectual property and then waiting until the environment is optimal for the launch or release. Few animals exhibit this type of alternation of generations.

Alternation of Generations

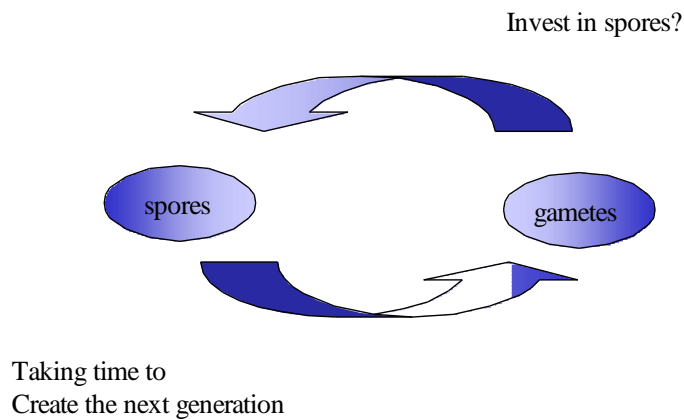


Figure 20: Alternation of generations model used in the cases

This alternation process can be looked upon as juvenile disposal that could equate to the spin out of new businesses. Another aspect of this model could be the social behaviour of kinship favouritism. This is often seen during business re-structure where non-logical appointments are made and certain individuals automatically get roles in a new organisation design. This is an example of parenting to ensure long-term survival of the genes. The Alternation model can be applied in the development of strategy when the seed stage can be seen as both the route to market and the way of dispersing a product, service or knowledge. Additionally the model can be used to examine what is locked or dormant in the business to see whether it can be germinated for future value. Previous customer behaviour and buying patterns would be an example of this. The future success of a business could be determined by a close examination of the previous interactions with the customer. This customer 'DNA' is locked in the 'seeds' of the system. Accessing this information will potentially change the future business strategy.

The Alternation model also provides a useful way of thinking about the supply chains of a business. In some cases the value can be added by two parts of the business coming together to create a solution for the customer. On other occasions, it needs input from a partner to complete the process. From an organization design point of view the business can design its structure and go to market strategy using the Alternation model.

Two hosted parasites

This parasitic model (Figure 21) could be seen as a sub-set of the Symbiosis model (**Error! Reference source not found.**) however there are sufficient attributes in this sub-system to make it a useful model for developing business analogies. The Two Hosted model identifies where success is derived from two very different environments at different points in the growth lifecycle. There are two important aspects to the model. The first is that the environments are different and that the business can be different. The second is that there is a link between both environments via a vector. The vector can be either completely independent or it can be transitory within the business. Whilst this model was initially based on the lifecycle of Malaria, other parasites can cycle through more than two hosts. The Two hosted model is therefore predicated on multiple changes all connected to the same lifecycle.

Two Hosted Parasites

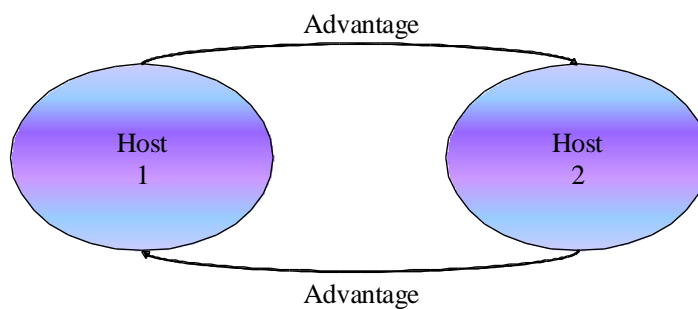


Figure 21: Two Hosted Parasites model used in the cases

At one level, this could be a sports complex that changes the sporting tuition offered depending on the season. The cycle uses the same resources configured in a different way with the fundamental resources used throughout the cycle. The richness of the model is found looking at the relationship between environment and resources.

By applying the Two Hosted model to a business, one of the initial areas to explore is where else could the business operate using the same resources or changed resources to generate value in a different environment. The next step is to decide how the movement in the second environment will be accomplished and whether this can be

done in a bi-polar way or whether a third stage is required. Each environment stage must sustain the business through the creation of added value. The business does not need to have anything obviously in common when compared between environments. The only requirement is that it can be connected to each sequential environment through a determined vector. The business benefits from the Two Hosted approach as it can move away from environments when they are less favourable returning later when the opportunity has improved. It could be used to justify a conglomerate business structure and the acquisition of what appear to be un-related businesses. This would be where the management expertise is moved between the environments optimizing the return based on the attractiveness of the industry. At one extreme, the business could open in one market, close, open in another market, close and then re-open in the original market. This runs counter-intuitively to the notion that the company and its products need to stay within one environment.

Past casting

The Past Casting model (Figure 21) was initially based on ecdysis in crabs (see page 44) although there are a number of species that exhibit ecdysis with examples in the insect, snake and crustacean worlds. The premise of the model is that what has made the business successful in the past must not be the biggest constraint to growth in the future. In crabs the exoskeleton, or shell, provides a range of functionality. It provides shelter, the ability to move, the ability to catch prey and feed, protection, camouflage, as a weapon, as a tool for digging and reproduction. The challenge for the crab is that it needs to grow and will therefore lose these functions.

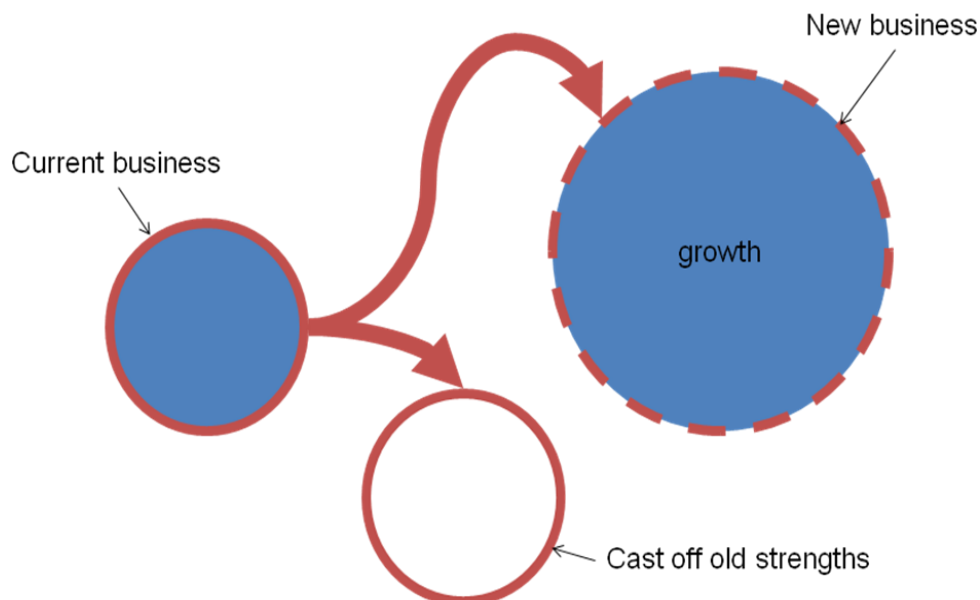


Figure 22: Past Casting model used in the cases

The Past Casting model asks a business to focus on what the business is best at and the attributes that made it successful. This is often counter-intuitive as most approaches to improvement are focused on what does not work and how can improvements be made. The assumption in this new approach is that what has made the business successful in the past could now be acting as a constraint. This model also draws from a number of biological layers. The first is physical where the exoskeleton (shell) acts as a constraint. The second is at a biochemical level where the process of ecdysis effectively recycles the key components of the shell, calcium, lipids, and essential minerals and then re-uses them in the formulation of the new shell. Another constraint is a process where ecdysis is mapped to a change management programme.

The shell level provided an initial assessment as to what may be constraining the growth. It can be used in a workshop situation and it challenges the beliefs and assumptions of the management team. The approach can also be applied for personal development, challenging skills and experience that has created past success but may no longer be appropriate in the future. The recycling view challenges the business (or the individual) to throw away what was useful in the past but is no longer appropriate. This past casting is the most challenging part. The final stage is to plan with biochemical precision the changes that are needed to design the new shell, recycle, cast out the no longer needed and make the transition between the old shell and the new shell. Like crabs the business will go through a period of vulnerability where the new shell is hardening. If crabs such as *Carcinus maenus* (the common shore crab) go through this process up to eighteen times in their four-year life then businesses need to build this philosophy into their plans for continued growth. One change of the shell will not be sufficient.

MRS GREN

The MRS GREN (page 41 and Figure 23) model works as both a diagnostic tool and a planning model. Each of the letters represents an attribute of a business. Collectively they assess whether the business is 'alive'. The model can be applied at all levels of the business from an industry level to a departmental level. The business is asked to score itself against each of the letter categories as they see themselves now and as they want to be. This model then provides a way of analysis the gaps between the two and a subsequent plan of action to close the gap can be developed. The key to this model is the different way it looks at the business, challenging their approach to energy use, waste management, nutrition of their operations and their people and the way in which they sense the environment. Using a simple scoring system that can be adapted to the circumstance of the analysis the MRS GREN model can quickly

identify the failures in the current business and, more importantly, the opportunities to be more alive.

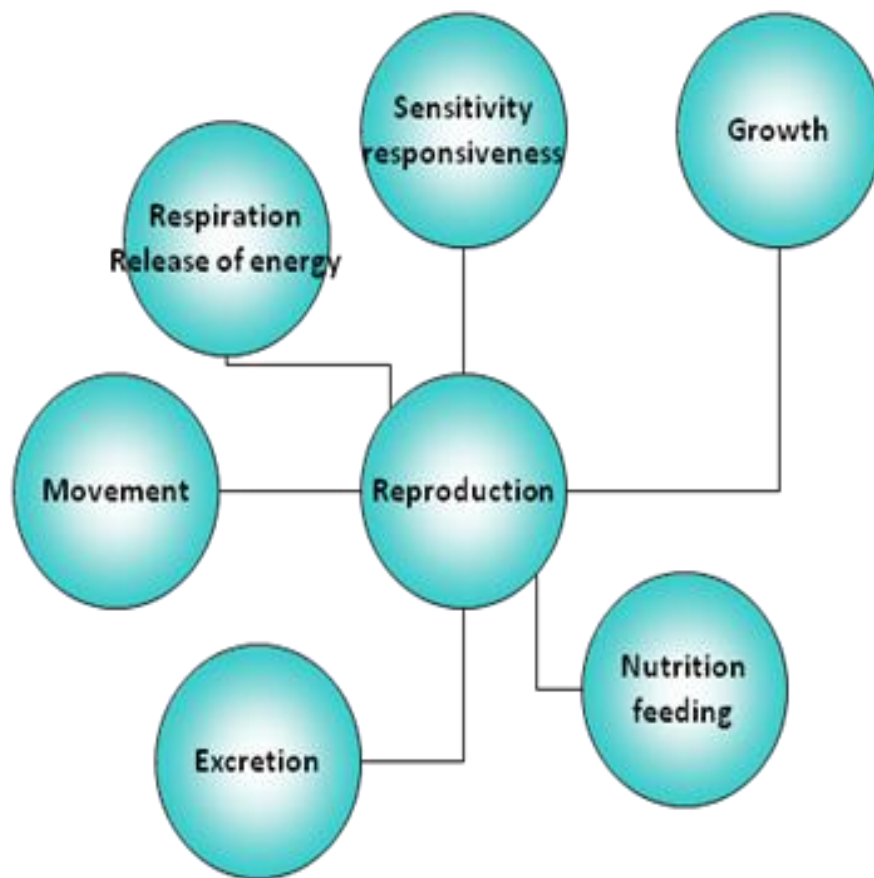


Figure 23: MRS GREN model used in the cases

This model can also be used to frame a problem for analysis. As a tool for scoping, it augments the more traditional approaches and encourages those doing the analysis to explore the more integrated sides of the problem.

Life stages in two environments

A number of insects go through pupation changing from one form to another. The transformation is irreversible and often results in a very different presentation. The classic transformation is the caterpillar to butterfly. Whilst this is often quoted as the metaphor for change, many change programmes often fail either to make a change or simply result in a faster caterpillar. The motivation behind this model was to bring more of the biology into play and to demonstrate the significant commitment the caterpillar is making in transforming to a butterfly and the reason why it is doing this. The Life Stage model (Figure 24) evaluates the two environments of current and future scenarios and challenges the business to understand its motivation to change.

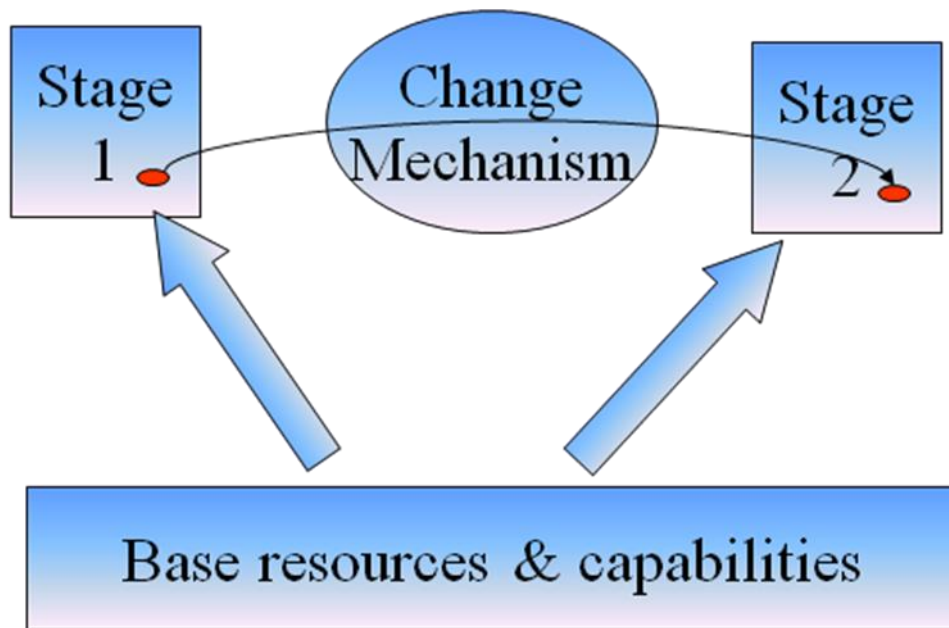


Figure 24: Life stages model used in the cases

Typically the caterpillar goes through a number of instars (pupae changes) before it makes the final change to butterfly and the model helps the business understand that more than one incremental change will be required before the final transformation stage can be achieved. The other important issue that this model helps resolve, is the degree and scale of changes required to make the transformation. The pupae stages are effectively molecular soup where rearrangements of the proteins happen. Whilst business leaders are enthusiastic about the butterfly outcome they are less motivated to make changes at the molecular level. By using the Life Stages model, leadership teams can determine which instar they are in and whether they are prepared and capable of making the transformation. It also challenges their preparedness to wait, doing nothing externally whilst the changes are happening.

Following transformation the model also helps identify the new behaviours, processes and measures that need to apply. The role of the butterfly is very different to the role of the caterpillar. An organization needs to ask itself if it is ready for that change.

Whilst there are undoubtedly many more systems that could have been used the models selected would at least be indicative. In taking a strategic view, it was felt that MRS GREN provided a useful way not only to group the models but also to draw an analogy between life and business and potentially have a role to act as an umbrella model for the other models.

Now that the business biomimetic models have been created, the next step is to test them. This has been done using the experimental approach in Chapter 5 Testing the biomimetic models, which follows and case studies that are described in Chapter 6 The application of biomimetic models in industry using case studies (see page 119).

Chapter 5 Testing the biomimetic models

To assess whether ideas from nature could improve business performance it was necessary to design a suitable way of testing the hypothesis. As the scope of the research was strategic business management then a mechanism similar to that used by business leaders today would be appropriate. To test the hypothesis it would be necessary to compare the results from traditional management models with the business biomimetic models. A classic experimental design (Bryman and Bell 2003) was adopted which seemed appropriate as the basis for the research was biological science. The method was extended to compare the two variables against a control. This experiment was designed to produce a test case where the results could be evaluated with the case studies (see page 119). Specifically the test case needed to test the hypothesis that the application of biomimetic models would have a positive impact on business performance. This was achieved using a basic controlled experiment with three businesses tested. One for the traditional management models and one for the business biomimetic models where the impact of the biomimetic models were compared with the impact of the management models. There was a third control group.

Standard experimental approach

The classic approach taken was structured as follows

- Aim – define the aim of the experiment
- Materials – define the businesses and therefore people involved
- KPI's – set the measures
- Materials – set the variables to be tested
- Method

Experimental design and validity

The purpose of the control group was to test the internal validity of the experimental results. There were a number of external factors such as the risk that participants react positively to the attention they were receiving (often referred to as the Hawthorne

effect)(Bryman and Bell 2003). As the businesses were randomly allocated to a group and the groups given the same level of attention this risk was mitigated. The other effect was history as one of the businesses selected had experience with biomimetics and another with traditional management models. The possible effects of the businesses selected and the impact on the results is discussed at the end of this Chapter.

Aim – define the aim of the experiment

The aim of the experiment was to compare the business biomimetic models with traditional management models by generating ideas to grow the identified businesses. The results of each test were validated against a control group. The effect of the ideas needed to be measured in terms of generation and potential application.

Materials – define the businesses and therefore people involved

In determining which businesses could be used as the basis for the test case the selected businesses needed to satisfy two criteria, accessibility and agreement. It was important that the chosen businesses would be accessible both in terms of availability of the people to take part in the test case and there was agreement to take part in the test case: This meant providing access to the business leaders and resources. The business needed to be willing to share its ideas in the test case and be prepared to take part in one of the test case streams.

Identifying three similar businesses for the test case meant defining what a business was. At its basic level a business has an expectation of profit, provides a product or service, does this in a repeatable way and has levels of financial control. Viewed this way a University is a business and it is possible to argue that a research group within a University is also a business. Using this as a reasonable definition of a business three research groups within the Department of Mechanical Engineering at the University of Bath were identified to take part in the test case. To take part each group needed a readily identifiable leader, a clear product or service and similar resources (headcount, seniority of people and budget). The group also needed to satisfy the selection criteria for a business outlined above.

KPI's – set the measures

Having decided to use three research groups as comparable businesses, the next step was to determine appropriate performance measures. After discussions with the three group leaders it was agreed that applying the measures used in the RAE 2001 (HERO 2001) would not only mean that the same standard measures used across all of the UK's higher education establishments was used, it would also act as a focus for the groups taking part in the test case. At the initial group leader briefing, a range of possible criteria from RAE 2001, were considered.

- Quality of publications – create a 'ranking' system based on what is 'best practice' for journal titles – based on high ,medium and low impact
- Number of publications – count the volume of publications submitted and published
- Postgraduate students –create a moving annual total to see how many students there are and what the trend is.
- Income government funds – how much money comes from the government as cash? This could be skewed by the University allocation system where funding is allocated based on the RAE score.
- Income industry funds – how much cash comes from industry
- Employee satisfaction – create an index to measure this, using something that is already good practice.
- Customer satisfaction – how satisfied were the recipients of research output.
- Management practices – the measurement of use of standard operating procedures to determine whether good practice was being adopted.
- Outside presentations and conferences – count the number of conferences, exhibition, papers, guest appearances, TV /Radio, letters, web papers etc
- Subcontracted work – which could be measured as the number of projects or number of days.

During the discussion, these were narrowed down to three key performance indicators (KPI's) which would indicate the success of the group. These were esteem, revenue and publications.

In addition to agreeing the KPI's, the group leaders also agreed to a set of responsibilities. These responsibilities included taking an active part in the test case, ensuring their teams attended each session and completed the feedback questionnaires. Adherence to these responsibilities would significantly reduce the risk of the group not following the test case process and so therefore was very important.

Materials – set the variables to be tested

The materials to be tested came from the business biomimetic models which were described in Chapter 4 and the traditional management models described in Chapter 2. Both sets of models would be standardised as a PowerPoint slide with a supporting explanation.

Method

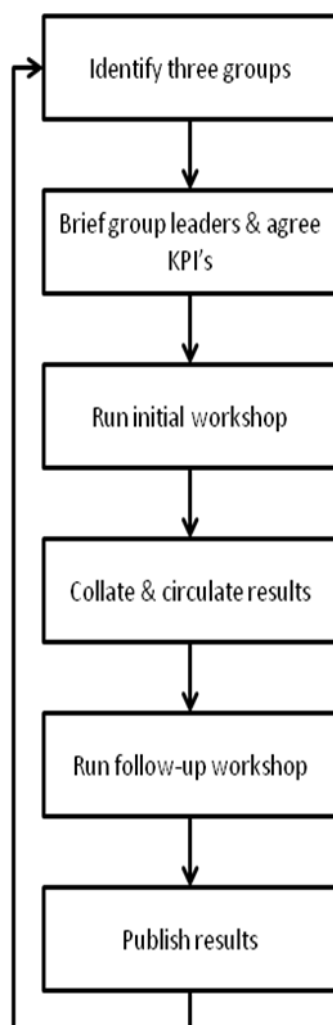


Figure 25: Test case method as a process

Identify the three groups, brief the group leaders and agree the KPI's

The experiment process shown in Figure 25 started with a kick off meeting with the three group leaders. It became apparent in the initial discussion with the group leaders that the research groups did not routinely view themselves as businesses. They also operated independently from each other, even though they were in the same department. Each followed a very different strategy and there was little guidance or intervention from the University. The preparation needed to include compelling reasons to take part as well as setting the context for the test case. The discussion included the background to the PhD and the purpose of the test case. We looked at the test case and the proposed KPI's to get agreement. The role and responsibilities of the three group leaders was linked to the benefits to the group leader (and group). Timescales and how we would communicate were also included.

Following agreement to participate in the test case, the group leaders selected a group letter. By selecting a letter A, B or C, the groups were then randomly allocated against the three test criteria. At the point of selection, they were unaware of which area their group would be tested against. Group A was to use Biomimetic models, group B was to use Business models and Group C was the control group. The control group agreed to participate as the results from the other groups would be shared at the conclusion of the thesis.

The initial workshop

In running each workshop time was taken to educate the group on three core aspects, what was in it for them, what benefit the test case could deliver and the test case process. The number of workshop participants ranged between nine to eleven and following the introductory briefing, they were divided into three or four sub-groups using one of the models. Three separate workshops were run, one for each group. Each group was briefed on the author, the background to the test case, the test case design and the key performance indicators.

At the respective group workshop, the business biomimetics models or the traditional management models were put onto cards. Group A randomly selected three of the business biomimetic cards. Group B randomly selected three of the traditional management models. Group C were given three cards that contained only the key performance indicators (esteem, revenue and journals). This mean that each group started with the same number of cards, each containing a stimulus for discussion.

At this stage each group knew that the purpose was to generate ideas and that the ideas needed to have an impact on the key performance indicators. In each sub-group, the author explained the model they had. Working together, they discussed how the selected model could help impact on revenue, esteem and journals. Each idea was then captured on a Post-It Note. Ideas were not allowed to be challenged. Two hours was allowed for this discussion.

Once the ideas had been captured, they were reviewed by the subgroup and a subjective assessment was made by the group as to which KPI they believed the idea would impact upon. This could be one, two or all three. Once agreed the Post-It Note was annotated with one or more of the following symbols E (esteem), R (revenue), J (journals). At this stage, each subgroup had a collection of ideas and an indication of which KPI the idea could potentially improve.

All sub-groups then rejoined as one group. The group as a whole were asked to collate the ideas together on the basis that they were similar. This was a subjective grouping. Once the ideas had been grouped, a title for each grouping was created. Each pile of post it notes with a unique title was picked by a pair of participants. Based on the content and further discussion they wrote a paragraph that explained the content they had examined.

Based on this paragraph a new summary description (word or sentence) was created. This new word or sentence was called a theme. All participants discussed these themes and if agreed, changes were made.

The data collected from the workshop contained the following information.

- Heading and description
- Idea
- Theme and description
- KPI (revenue, esteem, journals) prioritized for each theme
- Model number
- Group name (A, B or C)
- Date of workshop

This information was published on a secure website where data analysis could be carried out. A summary of the models used by each group is shown in Table 13

Circulate the results

Having collected the data from the workshop the next step was to establish the validity of the themes. If the models were going to have an impact on the three key performance indicators in practice then the groups would need to adopt the ideas and implement them. The next step of the test case was designed to test the validity of the themes.

This was done by creating a survey questionnaire that was emailed to each participant. The data was kept specific to each group so Group A results were sent only to Group A participants and a note accompanied the survey asking them to keep the information confidential.

The survey was sent as a spreadsheet with the Themes in column 1, the description in column 2 and the following questions in columns 3 to 7.

- How closely does this theme compare with what you actually do today? 10 = identical
- In your opinion, how much impact would this theme have on the KPI's if implemented? 10 = maximum impact on all KPI's
- How likely are you to take this theme forward? 10= very likely
- How much does this idea challenge the existing strategic thinking? 10 = completely new
- How radical is this theme for your group? 10 = very radical

Participants were asked to score the themes and send back the spreadsheet with their results. These results for each group are analysed later in this Chapter.

	Group A	Group B	Group C
Model 1	MRS GREN		
Model 2	Flocking		
Model 3	Symbiosis		
Model 4		Porter's 5 Forces	
Model 5		Resources Capabilities	
Model 6		Value Chain	
Model 7			Journals ⁸
Model 8			Esteem
Model 9			Income

Table 13: This table shows all the models used by the three groups (random selection by the group)

The ideas were reviewed and three were taken forward for implementation. The review process needed to be carried out with at least 80% of the team that created the ideas. Once the ideas had been selected, they were added to the idea template.

The follow up workshop

The final step of the test case was to take the results from the first workshop supported by the feedback from the questionnaire and analyse these results in a second workshop. The purpose of this was to agree which themes to take forward for the group, to identify projects or initiatives that supported the themes, to set high-level objectives for the projects and to agree project owners and scope.

Each group had its own workshop that started with a review of the results and general observations. The prioritisation of the themes had been evaluated via the website feedback and questionnaire. These outputs were discussed with the group to see whether they agreed with the overall result based on their individual feedback.

The group looked at each theme in turn and asked, "What could we do?" It agreed the assessment criteria, which was used to select one or more themes. The suggested testing criteria were based on Johnson & Scholes (Johnson and Scholes 1993) which tested for suitability, feasibility and acceptability and Rumelt (Rumelt 1995) which

⁸ In the control group (group C) the KPI's were used as models to structure the workshop

tested for consistency, consonance and acceptability. The grid used to evaluate these criteria is shown in Table 14.

Theme	Project idea	Suitability	Feasibility	Acceptability	Consistency	Consonance	Advantage

Table 14: Evaluation grid used to test validity of ideas.

The evaluation was carried out using the following project selection criteria definitions. Each theme was evaluated on a scale of 1 to 10 based on the assessors view

Suitability- the extent to which a project matches the needs identified. Does it overcome an identified weakness or threat?

Feasibility – how well will this work in practise and how difficult might it be to achieve?

Acceptability – how will stakeholders feel about the outcome of the project n terms of risk, ‘profitability’, ethics and relationships?

Consistency – does the project present mutually consistent goals and policies? It must create more value than it costs and compete with other organisations

Consonance – creation of social value – is enough value being created to sustain the group in the long term?

Advantage – can the group capture enough of the value that it creates such as superior skills, superior resources, and superior position?

The group sorted the themes into three categories, will do, might do, and will not do. For each selected theme a high-level project plan and ownership was agreed. For each

project selected the project leader was asked to agree with the group what the objectives would be, using the initial objectives for the test case of Esteem, Revenue and Journals to determine the priority. This information was collated and sent to the project owners and other members of the group following the workshop.

Test case results

The results for the three groups are compared before the detailed results for each group are presented.

When viewed together the variation between senior members of each group can be seen in Figure 26. Group A members exhibit a similar response whilst Group C exhibit a wide range of responses. Nine out of the ten results show a negative correlation. They demonstrate a decreasing linear relationship between the likelihood of implementation of a radical idea. Overall the more radical an idea was the less likely that this would be implemented. This then challenges the basis for innovative idea generation. By splitting the method into generation then evaluation, the influence of implementation constraint was minimised. If one accepts that a medium correlation value exists between ± 0.3 and ± 0.5 and that a strong correlation exists between ± 0.5 and ± 1.0 then eight of the ten shows a correlation (mainly negative) between likely and radical.

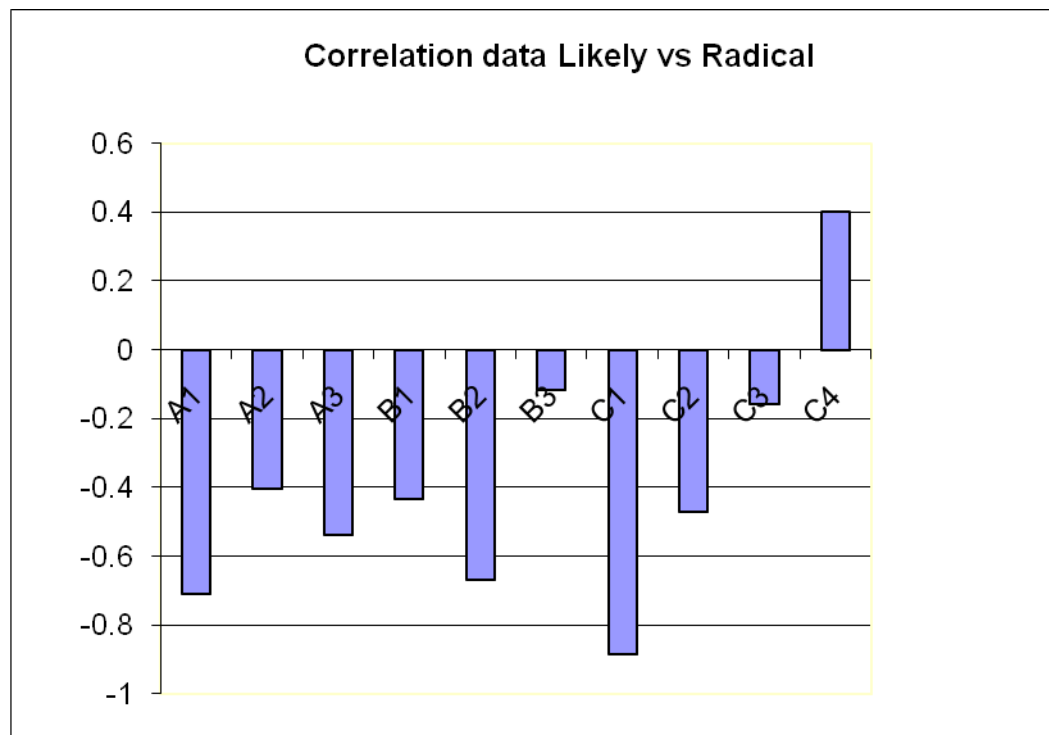


Figure 26: Correlation between likely and radical for the senior members of each group

Figure 27 shows the number of ideas per person and the average number of headings per person. The number of headings directly equates to the number of themes. It shows a similarity between the three groups in terms of headings. Group B produced a higher number of ideas per person. Groups A and B produced a higher number of ideas per person than the control group (Group C). This is an expected response from a group that receives a prompted intervention. The data seems to support the null hypothesis in that there is no difference between Groups A and B in terms of number of ideas produced per head.

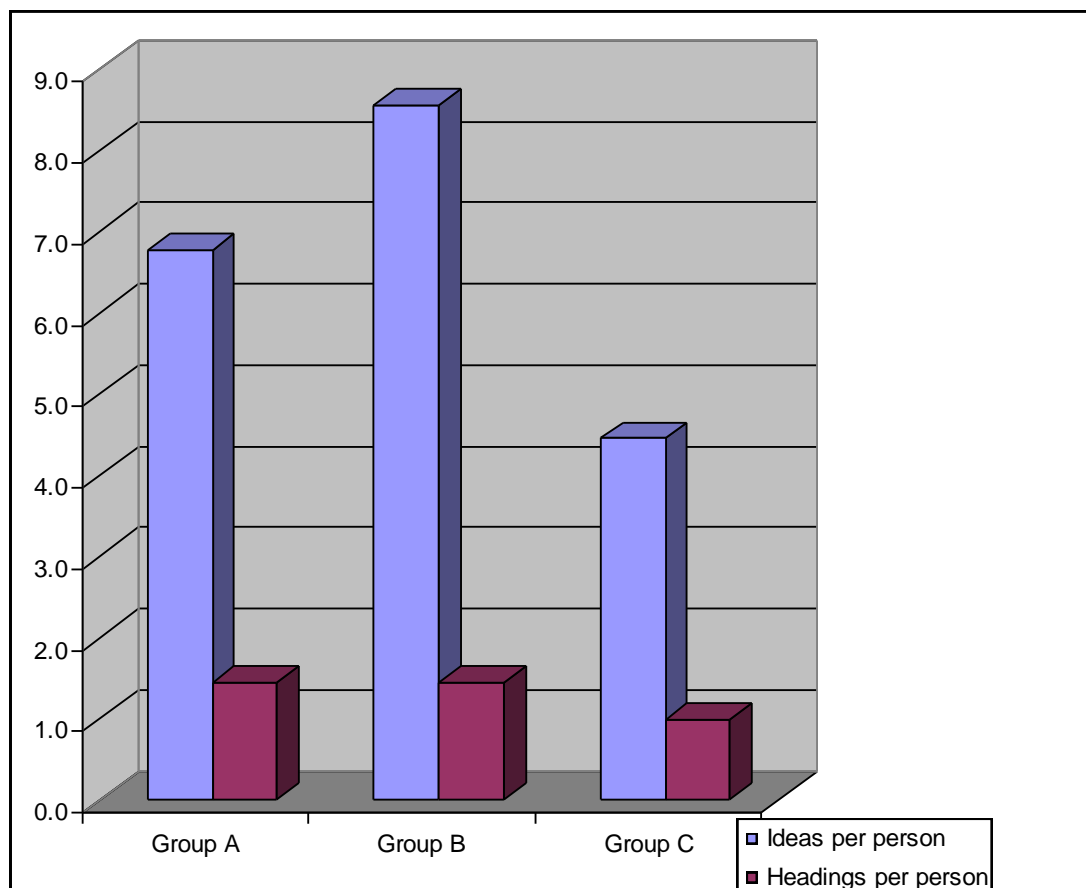


Figure 27: Comparison of ideas per group and per person

Further analysis shows the differences between the group in terms of ideas, headings and the number of people in the group. Group C shows a lower number of ideas per person. The challenge in providing a control group for this test case meant that there

were no independent models to test. The approach relied on the collective experience of the group. This assumed that all three groups had identical backgrounds.

Group	Headings	Ideas	Headcount	Group	Ideas per person	Headings per person	Ideas per heading
Group A	13	61	9	Group A	6.8	1.4	4.7
Group B	13	77	9	Group B	8.6	1.4	5.9
Group C	11	49	11	Group C	4.5	1.0	4.5
total	37	187	29	total			

Table 15: Comparison of ideas for the three groups

Headings per KPI

When compared to the three KPI's (**Error! Reference source not found.**) there is a marked difference between Group B and the other groups in terms of revenue.

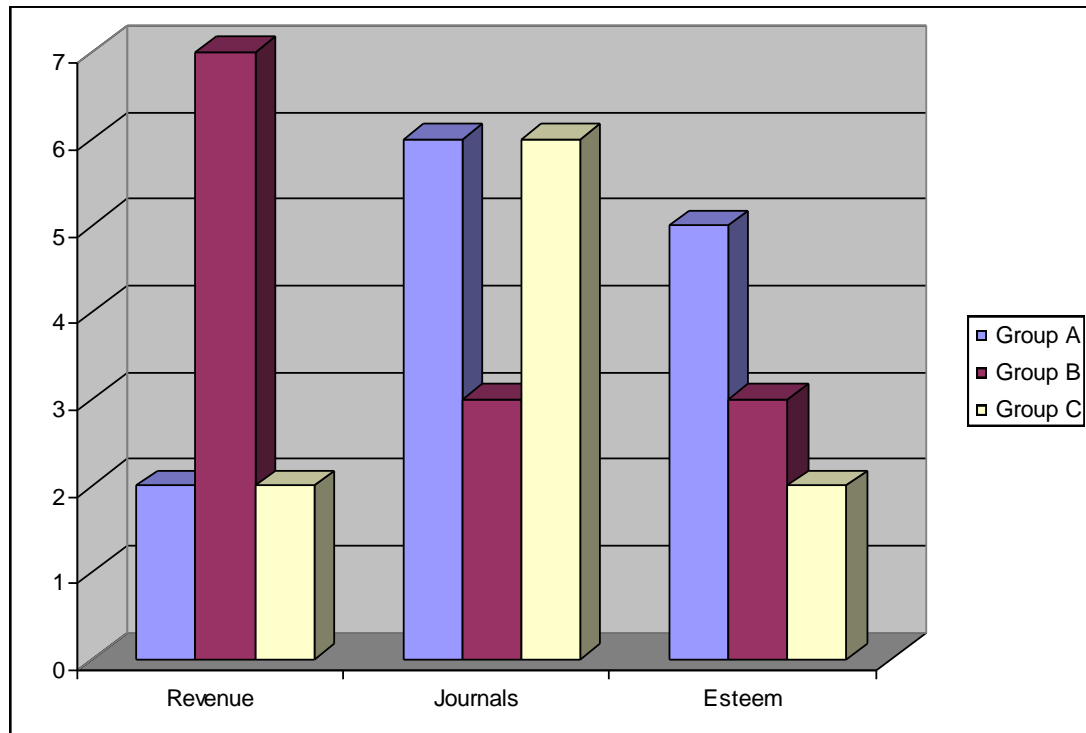


Figure 28: Impact on the three KPI's (number of headings per KPI)

Whilst Group B generated the highest number of headings for revenue, it was the lowest in terms of headings for journals and esteem. Group A had the highest total for journals and esteem. Table 15 shows the contrast between groups. It is possible to conclude that short terms revenue improvements are best achieved through the use of conventional management models. This assumes that the number of headings equates to the corresponding increase in revenue when implemented. It also assumes that the ideas would be implemented in an equally effective manner. The case studies results confirm that a combination of conventional management models and the biomimetic business models create the best outcome.

Ideas generated by model

During the test case, it was possible to capture the ideas generated when brainstorming ideas with each model. Whilst using the Porter 5 forces model generated the highest number of ideas, they classified into just four headings which was similar to other models. This could be an example of the business management models generating a high number of similar ideas.

Model	Model description	Model group	Number of ideas	Number of headings	Average number of ideas per heading	By Group
Model 01	MRS GREN	Biomimetic	26	6	4.3	
Model 02	Flocking	Biomimetic	26	4	6.5	
Model 04	Symbiosis	Biomimetic	9	3	3.0	61
Model 05	5 Forces	Business	47	4	11.8	
Model 06	Resources	Business	13	5	2.6	
Model 07	Value Chain	Business	17	4	4.3	77

Model 08	Papers	Control	17	6	2.8	
Model 09	Esteem	Control	13	2	6.5	
Model 10	Income	Control	19	2	9.5	49
		Total	187	36	5.2	

Table 16: Number of ideas and headings per model, biomimetic (A), business (B), control (C)

In Table 16 the symbiosis model had the lowest number of ideas. The group found this was the most difficult model to understand.

Correlation analysis

Error! Reference source not found. Shows comparisons between the groups. Group C was likely to carry through an idea if it had an impact on the KPI's. Group A was neither likely nor unlikely to do the same. Group B was likely to carry on with what it did today and Groups A and C were unlikely to carry through anything that was radical or challenged their thinking when compared to today.

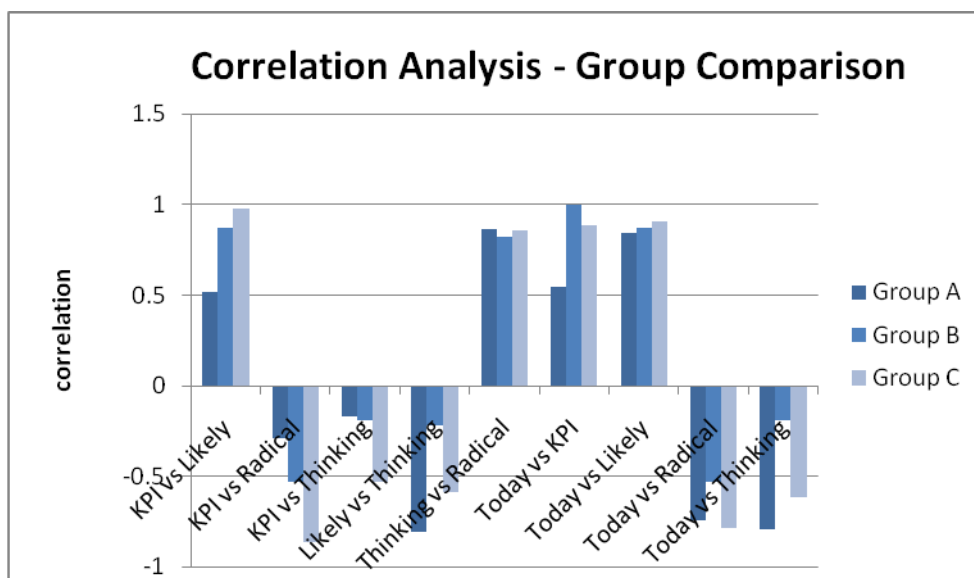


Figure 29: Correlation analysis group comparison

When compared together the range of themes can be seen. The information sought was the impact of the control on the test case and whether it was possible to show similarities and thereby identify the differences that conventional business generated compared to what business biomimetics produced.

The interpretation is subjective unless the themes have been given the same name by the group. Even in this case, it may be that they have collated different ideas and the name is a coincidence. Table 17 attempts to align the themes.

Group C	Group A	Group B
become a company	create a centre of excellence	business development
maximum re-use	re-organise and use people differently	core competency
government funding	target marketing	change to project structure
team work	build relationships	operations management
marketing strategy	apply for grants	team work
streamline operations, improve profitability	mass media marketing	innovation
generate revenue	better use of resources	create marketing department
better use of resources	better use of resources	location
better use of people	marketing strategy	management processes
being unique	relationship and image	marketing strategy
	better use of resources	create research strategy
	efficiency and effectiveness	better use of resources
	cost management	better use of resources

Table 17: Comparing themes from each group to determine the control effect. Control Group C in the left column compared to the Biomimetic (Group A) and Management (Group C)

There appears to be a good match between the themes and this raises the question whether it would be possible to predict themes for any future test case without carrying out the idea generation stage. Would it be possible to produce the top 13 themes for any business change problem?

To avoid any contamination of the results this information was not shared between the three groups. The three groups generated a total of 187 ideas. There are three key result areas. The first captures the ideas generated at the initial workshop. The second captures the ranking and prioritisation from the survey and the final set of results captures the information from the second workshop. The information has been presented in its entirety before being analysed using some simple data views. Due to the small size of the groups and the data generated, it was inappropriate to carry out detailed statistical analysis. The data has been examined for patterns and key differences identified with a key focus on the likelihood of the idea being implemented. This is a small sample size with the inherent statistical risk in drawing generalisations from the data present however the conclusions drawn from the test case are also supported by observations in the case studies.

The results have been analysed from two perspectives which are did the business biomimetic approach generate ideas and how did those ideas compare to the traditional management models. It is recognised that there will be variability when the approach is applied to a further University group or a commercial organisation. When the numerical data is combined with the feedback from the groups and this is compared to the case studies some compelling evidence emerges which are examined in the conclusion. What follows is the detail results for each group.

Group A (Biomimetic)

Initial workshop

The ideas generated by group A from the initial workshop are presented in the appendix In Table 18 the headings and the themes they are presented in the order in which the ideas were entered into the database. This order does not have any test case significance.

Group A selected themes	
Theme	Heading
create a centre of excellence	Attracting researchers
re-organise and use people differently	Better use of junior staff (post docs)
target marketing	Disseminate ideas to public / popularise
build relationships	getting out more
apply for grants	Grant application proposals
mass media marketing	Journal publications
better use of resources	Optimisation of working environment
better use of resources	Organisation? Efficiency of use of resources
marketing strategy	Respond to enquiries
relationship and image	Social mechanisms
better use of resources	Teaching issues
efficiency and effectiveness	Time Management
cost management	Time Optimisation

Table 18: Group A selected themes with original headings

Survey results

The themes were used as the basis for the survey questionnaire. The results of the survey have been collated based on the averages of the feedback from each group member. The factors (range between 0 and 10) represented in Table 19 are summarised as:-

- Today – how close is this theme to what actually happens today in the group?
- KPI – how closely does this theme achieve the KPI's
- Likely – how likely is the group to adopt this theme?
- Thinking – how challenging to the current thinking is this idea?
- Radical – how radical is this theme compared to the group today⁹?

⁹ This measure was a test of how far off normal the theme was for the group

Theme	Today	KPI	Likely	Thinking	Radical
apply for grants	8.7	9.5	8.7	1.7	1.7
cost management	4.7	8.5	5.7	4.0	3.7
mass media marketing	6.0	9.5	7.0	4.0	3.3
efficiency and effectiveness	5.7	7.5	6.3	2.7	2.3
create a centre of excellence	5.3	6.0	6.3	2.0	1.7
target marketing	3.7	7.0	5.0	4.3	4.3
better use of resources (research knowledge)	3.0	8.0	5.0	4.5	4.5
marketing strategy	4.0	7.5	4.7	3.7	4.0
build relationships	4.3	5.0	6.7	3.0	2.7
better use of resources(assets)	6.3	5.5	4.7	2.7	2.7
better use of resources (people)	6.0	5.5	5.3	2.3	2.3
relationship and image	4.3	7.0	4.7	5.3	5.3
re-organise and use people differently	2.0	6.5	4.0	6.7	6.3

Table 19: Group A survey results

Selection criteria

There were 35 themes generated across the three workshops, each of these themes build upon an aggregated set of ideas. As this number of themes would be too much for the groups to implement, a set of criteria were devised. These criteria would filter the themes into a prioritised list for the second workshop based on their answers to the survey questions and the importance of type of theme to the success of the group. A number of factors were considered:-

- Identify themes that would have the best possible impact on the KPI's
- Identify themes that they would be likely to implement
- Identify themes that they thought radical
- Identify themes that they thought challenged their thinking
- Select themes that they had ranked highly
- Select themes that created revenue over esteem and journals

- Select themes that were not similar to those in the control group (keep themes from the control group that were not in the other groups)

This was achieved by taking the average of the responses to each theme and keeping those with a value greater than or equal to 5.0. Factors were given for the type of KPI and the relative ranking of the theme compared to the other themes. The final selection of themes was based on the combination of the above approaches.

Selection level 1 – survey results

Any question with an average score of 5 or more was selected. By taking the midpoint, the groups could focus on the themes that were more likely to appeal to the group. If three or more questions met this criteria, an initial selection was made.

Selection level 2 – normalized against control

The themes generated by the control were compared to the biomimetic or management approach. They were filtered at three stages with increased degrees of fuzziness as closely matched, approximately matched or roughly matched.

Selection level 3 – ranking

Each themes workshop rank was taken from the first workshop. The themes had a primary R, E or J key performance indicator. A factor was applied for revenue (0.5); esteem (0.4) and journals (0.3) where each factor has been assessed as a contribution to the success of the group on the following basis. There is no group without revenue, esteem makes the group attract revenue and key researchers and Journals are one measure of output (although not necessarily of value)

Theme selection

The factors were used to prioritise the themes. A theme with a primary KPI of R would be selected in preference over a theme with a priority of J. Where there was, more than one theme with the same KPI rank the themes were then graded between 1.0 and 0.1 in 0.2 increments. 1.0 equal to top position and 0.1 equal to 5th position. Sixth place was equal to 0.1 and 7th place equal to 0.05. This was repeated for each group.

Second workshop

At the second workshop, the group used the evaluation criteria (Table 14) to identify possible projects that could be implemented to deliver the key performance indicators. The groups chose a value added project for a first year post graduate, shorter-term deadlines to encourage productivity, to submit regular papers into lower quality publications and the development of a website.

Analysis of Group A results

By tracking where the ideas came from, it was possible to identify the prime model that generated the theme. The relationship between model and theme is shown in Table 20

Model	Theme	Description	Group
MRS GREN	create a centre of excellence	Change the way in which the group presents to potential researchers. Create an identity that would be attractive. Examples could be to have unique equipment or to promote an 'attractive' research area. This could be done by creating a centre of excellence then promoting it to the research community.	A
MRS GREN	re-organise and use people differently	Utilise the staff that move through the group better. One area would be post docs and research officers. We could change the way in which we recognise contribution to create a level of competitiveness. We should take an overview of the resources and decide if there are any opportunities to collaborate within the group. This would probably involve post docs working in areas that were not their own	A
MRS GREN	build relationships	Target a number of key conferences and seminars and spend time at these building relationships and networks.	A
MRS GREN	apply for grants	Put effort into grant applications. Often the effort in a small grant will be the same as a large one.	A

MRS GREN	mass media marketing	Change the approach to Journals. Go for high volume and acceptable quality. Aim for subjects where we will get maximum exposure and the greatest number of citations. Offer to collaborate with others so that we increase the number of times we appear in print.	A
MRS GREN	better use of resources	Do we successfully execute against our commitments to our stakeholders, for example do we do the best in teaching? Should we consider using our resources differently to address this and how do we manage choice. Is there a level of ambiguity that makes us inefficient?	A
Flocking	target marketing	Create a marketing strategy that communicates within the group and provides a targeted approach to our target audience	A
Flocking	marketing strategy	Do we have a marketing strategy and what is our proposition? Do we even know what others in the group do? Do we present a single integrated view to the outside? What do we use as marketing fulfilment?	A
Flocking	efficiency and effectiveness	Are there changes that we can make to process that would improve the effectiveness and efficiency of the group. Do we waste resources such as time and are there bottlenecks that could be addressed?	A
Symbiosis	better use of resources	We seem to be working in difficult ways.	A
Symbiosis	better use of resources	Could we use our people in a better way? Do we have the right people? How much waste is there and what can we do about it? Do we have an integrated approach that gets the best from everyone? Does everyone know what the plan is and where they fit?	A

Symbiosis	relationship and image	How can we use social mechanisms to improve? Are there fashionable ideas that we exploit as a priority? How do we become more attractive?	A
Symbiosis	cost management	Do we waste resources such as time? Do we have a balance between all our requirements? Could we make a significant reduction in the costs of the work we do? Do we have the right competency on each task? How can we help each other?	A

Table 20: Group A themes generated by model

The survey data was analysed using correlation coefficients¹⁰ to identify the correlation between the factors identified in the survey (Salkind 2010). The purpose was to determine what could happen to an idea that was generated. Ideally, an idea would have a high likelihood of being implemented and that this idea would have a high match to the KPI's.

Correlation analysis for Group A	
Thinking vs. Radical	0.861813
Today vs. Likely	0.840625
Today vs. KPI	0.545446
KPI vs. Likely	0.516743
KPI vs. Thinking	-0.16775
KPI vs. Radical	-0.28832
Likely vs. Radical	-0.70778
Today vs. Radical	-0.74299
Today vs. Thinking	-0.7949
Likely vs. Thinking	-0.80599

Table 21: Correlation analysis for Group A

¹⁰ The type used is the Pearson product-moment correlation

Based on this analysis Group A were unlikely to implement anything that was radical. The survey results also show a polarisation towards the familiar and a tendency to avoid radical themes. Because of the low number of data points, the detail of the above analysis does not have statistical significance although it is indicative of the group's behaviour. Further evidence is provide in Table 21 which shows the range of responses where there is often a good relationship between a theme that is not radical and its likelihood of being taken forward.

When the senior members were examined at the individual level one member of the group believed that the themes were not radical nor would they be likely to be implemented. This was different to the other senior members who had a more distributed range. It could indicate some other underlying issue.

Group B (Business)

The ideas generated by group B from the initial workshop are presented in the appendix In Table 18 the headings and the themes they are presented in the order in which the ideas were entered into the database. This order does not have any test case significance. It uses the same format as those for Group A starting with the ideas from the initial workshop

As before, the ideas were consolidated into Headings that were then converted into Themes. These are shown in Table 22.

Theme Survey	Heading
business development	Communication
core competency	core competency
change to project structure	cross working
operations management	Day to day running
team work	form strategy
innovation	Innovation
create marketing department	Knowledge sharing
location	Location
management processes	Management
marketing strategy	Profile raising
create research strategy	Project identification/funding
better use of resources	Resources
better use of resources	Technology

Table 22: Group B selected themes and original heading

Survey

Theme	Today	KPI	Likely	Thinking	Radical
core competency	5.3	6.3	6.0	3.7	3.7
change to project structure	5.0	4.7	5.0	4.3	4.3
team work	5.7	6.7	6.0	3.7	3.7
better use of resources (people)	5.0	7.3	6.0	4.7	4.3
management processes	6.3	7.0	6.0	3.7	4.0
business development	5.3	5.3	4.7	4.7	4.0
Location	4.3	3.0	3.0	6.0	7.3
Innovation	6.0	7.3	6.0	4.7	4.7
marketing strategy	7.5	8.0	7.5	5.0	3.5
create marketing department	5.7	6.3	6.3	5.3	6.3
create research strategy	7.3	8.0	7.7	4.0	3.7
better use of resources (technology)	5.3	7.0	6.3	5.0	5.0
operations management	5.3	5.3	5.3	5.3	5.0

Table 23: Group B survey results

Selection criteria

Group B selected two themes to take forward to the second workshop. The themes cannot be compared to those generated by Group A as the source of ideas and the responses to the survey was particular only to Group B. However, the fact that Group B only had two themes to take forward suggests more consolidation or a consistency in the ideas generated. The themes were core competency and a change to project structure. Group B were reminded about the ideas they had generated in the first workshop, which are shown in Table 13.

Second workshop

Concerned by their lack of themes at the second workshop Group B decided to revisit all of the themes they had created in the initial workshop and use these as the basis for

defining projects. Results showed that the chosen themes were core competency, better use of resources and business development.

Analysis of Group B results

Table 24 shows the link between the model used and the theme. Each model generated a similar number of themes.

Model	Theme	Description
Five Forces	operations management	There is a real need to look at how the group is run. A number of process areas have been identified as sub optimal. There are also questions about management style and it is believed that a review of these areas (process, organisation and technology) will lead to an increase in the group's productivity. We should also look at the objectives we have and how the group is measured. It is believed that a change in approach will improve productivity.
Five Forces	create marketing department	Develop new processes to manage the information we have. Create a scanning mechanism for opportunities for funding. Understand where the best opportunities for publishing. Look at the channels we use such as the web and ensure that it is integrated with the other channels. Be aware of the competition and what our partners are doing.
Five Forces	marketing strategy	Create a marketing strategy. Look at what we do, how we do it and the channels we use. What could be done to make a significant change? What do we want to be famous for?
Five Forces	create research strategy	Do we have a research strategy? Do we know the research we are targeting to do in the future? Do we have a pipeline of research that achieves our research objectives? Have we identified potential partners and collaborators? Do we have a finance plan that supports our strategy? When do we spend time thinking?

Resources & Capabilities	business development	Focus on the relationships we have both inside and outside the group. Create a pro-active marketing campaign to improve the inbound and outbound communications. Look at ways we could do business development. Introduce new metrics such as income, acquisition and customer.
Resources & Capabilities	change to project structure	Could we set up the groups in a different way to maximise our performance? Could we use projects teams that were research focused rather than the existing group structure?
Resources & Capabilities	team work	Get members of the group working as a team. Co-operate on research areas and have a clear strategy to innovate and research. Have clear responsibilities for teaching and research. Use targets and goals to improve motivation and focus.
Resources & Capabilities	location	Consider our location. Does it still fit with our strategy? Could we do more by co-locating with our customers?
Resources & Capabilities	better use of resources	Do we get the best use form the resources we have? Are there capital resources that we could use better?
Value chain	core competency	We need to focus on what we are good at. And if that is teaching then that is what we should do. We should look at our core strengths and focus on the key ones. This might mean splitting the group or operating with a number of sub groups.
Value chain	innovation	Create an environment that encourages innovation. Look at the IP that we have generated and seek ways to exploit this. Find ways to think more about the opportunities for further research. Actively encourage new ideas across the group.
Value chain	management processes	Introduce management processes to the group. Look at team building and

		communication to consider how we generate ideas and how we build relationship with customers.
Value chain	better use of resources	Can we make better use of our resources in which we can use our capital investments to generate income? Are there any lessons from manufacturing that we can use to optimise the use of existing resources?

Table 24: Group B themes generated by model

The correlation in Table 25 was compiled with the limited data volumes. However, the results still demonstrate the behavioural differences of the group.

Correlation analysis for Group B	
Today vs. KPI	1
Today vs. Likely	0.86822
KPI vs. Likely	0.86822
Thinking vs. Radical	0.822339
Today vs. Thinking	-0.1896
KPI vs. Thinking	-0.1896
Likely vs. Thinking	-0.2195
Likely vs. radical	-0.43424
Today vs. Radical	-0.53278
KPI vs. Radical	-0.53278

Table 25: Correlation analysis for Group B

Group B are extremely likely to implement ideas that are the same as what they do today. They are unlikely to implement anything that they believe requires thinking or is radical. Overall Group B was likely to implement less radical themes

Looking at the senior members of the group there is a difference between the likelihood of implementing radical themes. Like Group A most responses for Group B are clustered in the 'more likely to implement if less radical' area. The second workshop adds a level of confirmation that the ideas can be taken forward. The limits imposed by the survey selection significantly reduced the themes available for

discussion by the group. This may mean that the business management models provide less concrete themes to take forward or this was a function of the group. Either way there was less to work with in terms of richness of idea and enthusiasm than with group A.

Group C (Control)

The data has been presented to show the range of ideas generated. It uses the same format as those for Group's A and B starting with the ideas from the initial workshop

Group C themes	
Theme Survey	Heading
become a company	Commercial streams (industrial funds)
maximum re-use	Poor papers (reduce quality)
government funding	Government funding
team work	Group Integration
marketing strategy	Marketing and image
streamline operations, improve profitability	More facilities
generate revenue	More money
better use of resources	More research time
better use of people	More staff
being unique	Specialised research

Table 26: Group C selected themes with original headings

Survey results

The results from the survey questionnaire are shown in Table 27. Marketing was seen as a theme least like the groups activity today. However, at a score of 5.8 it appears unlikely that they will implement this theme.

Theme	Today	KPI	Likely	Thinking	Radical
generate revenue	8.0	8.0	8.8	2.5	2.5
being unique	5.8	6.8	6.5	3.5	3.5
government funding	3.7	6.7	4.0	5.0	5.0
streamline operations, improve profitability	5.8	5.3	5.5	4.3	3.3
better use of resources	5.5	7.3	7.3	4.0	3.5
marketing strategy	4.0	5.5	5.8	4.0	3.3
better use of people	7.0	8.0	7.8	3.0	3.0
become a company	6.5	4.3	5.5	4.0	6.0
maximum re-use	3.3	5.3	3.0	2.0	3.3
team work	8.3	6.3	8.3	2.3	1.5

Table 27: Group C survey results

Based on the survey responses Group C selected three themes to take forward to the second workshop, which were to generate revenue, being unique and government funding.

Second workshop

Second workshop results selected being unique and government funding to take forward.

Analysis of Group C results

Model	Theme	Description	Group
Journals	maximum re-use	Make the maximum use of all IP that could be converted into a paper. This would also include looking at lower quality journals. The key attribute here is volume. To maximise the results focus on work that can be reused a number of times.	C
Journals	team work	Take time to integrate the whole group. Communicate the span of research so that everyone knows what is being done. Integrate technical and research staff to get the best results. Take time to communicate with each other.	C
Journals	streamline operations, improve profitability	See if we can streamline operations. Do we have the right facilities? Do we need more or less?	C
Journals	generate revenue	How do we generate more money for investment into the group?	C
Journals	better use of resources	How do we get more value from what we do? Consider reviewing how we do research to see if there are ways in which we can more form the limited resources we have. Have a clear strategy for the use of resources then stick to it. Have clear plans for innovation, known projects and business development. Are doing the right things?	C
Journals	better use of people	Are we making the best use of our people? Could we allocate resources in a different way? Are there seasonal changes that we could use to our advantage? Are their opportunities to use non-research staff to help increase the outputs?	C
Esteem	marketing strategy	Create a marketing strategy. Look at what we say, how we say it. The channels we use and how we follow up and build relationships.	C

Esteem	being unique	What makes us unique? What is our unique selling proposition? What do we want to be famous for? Are there any parts of what we do that could be packed up in a way that they attract interest? (i.e. courses, books etc). Could we create a demand for specialised services?	C
Income	become a company	This theme is about providing real focus to developing profitable relationships with industry. We need to decide what our unique proposition is and develop this with existing and new industry contacts. We could create a consulting team and offer this to industry. We could also explore hiring out the team or the facilities for commercial research. We could also review the relationship with the University and discuss overhead costs. This suggests we would be willing to operate as a Profit & Loss operation. Later we could explore the IP opportunities and decide whether there are spin off opportunities. In working this way, we would need to keep tight control over project scope and deliverables.	C
Income	government funding	Focus on government funding. Identify the 'hot' areas and put a concerted effort into attracting funding. Look at ways in which we can use interdisciplinary research to broaden the number of funding avenues we can explore. Look at ways we can use the funding to attract and retain new researchers. Put an effort into writing grant applications.	C

Table 28: Group C themes generated by model

Correlation analysis	
KPI vs. Likely	0.975629
Today vs. Likely	0.90856
Today vs. KPI	0.886621
Thinking vs. Radical	0.853829
Likely vs. radical	-0.88562
KPI vs. Thinking	-0.533
Likely vs. Thinking	-0.58869
Today vs. Thinking	-0.6168
Today vs. Radical	-0.78302
KPI vs. Radical	-0.86177

Table 29: Correlation analysis for Group C

Group C showed a similar pattern to both Groups A and B in that it was less likely to implement themes that were radical. It was highly likely to implement less radical ideas. There was a much wider range of results between the senior members of the group with the leader less likely than other members to implement radical ideas. Group C has a strong track record in delivering revenue and in collaboration with industry. The areas they decided to focus on were very similar to the work they were already doing. They were very unlikely to tackle anything they believed to be radical. Overall, they were satisfied with the current situation and wanted to concentrate on improvement. They accepted that they tended to focus on the short-term generation of revenue and delivery of projects. There was no long-term focus nor was there an appetite to explore this approach. Overall the group was more cohesive as a team and were more aligned than the other groups in the delivery targets. The group had a much more directive leadership style with a tighter command and control approach.

Test case discussion

In comparing the business biomimetic models with the conventional business management models an apparent difference was observed for revenue generation. There was no apparent difference when comparing the results for 'Journals' and a significant difference when comparing the results for 'Esteem'. It is possible to

examine these against the typical behaviours of the research groups. A key driver for a research group is to generate revenue, either through industry sponsorship or grants. Whilst each group is driven by the need for revenue, the motivation is often different and the strategy adopted by groups can range from a high focus on industry to a complete reliance on grant funding. Allowing for such behavioural differences does not explain the gaps between the management results and the biomimetic and control groups. Based on the results it is possible to conclude that the increased number of ideas from revenue observed were as a direct effect of applying the management models. However, there may be differences due to the make-up of the group. The biomimetics models showed a significant difference in terms of esteem and it is possible to conclude that this is due to the longer-term survival aspects of nature. The management models generated 40% less than the biomimetic models and the control 60% less.

Whilst group B generated more ideas than groups A or C for revenue, they were less likely to implement the ideas if they were radical, with the more senior members of the group unlikely to implement any radical ideas. Therefore, whilst conventional management models generate more ideas they are unlikely to be implemented if the management team feel they are too radical. It is possible to envisage a scenario where a business has previously generated ideas that have not been implemented. It is therefore likely that managers have decided the ideas did not work, when it is more likely that they did not ever implement, or only partially implemented, the idea. This corporate memory (Beckett 2000) is likely to reinforce the behaviour that these and subsequent ideas are not implemented.

Members of group A were more likely to implement their ideas, although they had fewer ideas. If this likelihood is then considered in context with the higher number of esteem ideas then group, A is more likely to implement their ideas. The test case design did not include a way of factoring the ideas in terms of likelihood of implementation although that is an important consideration.

When the group leaders were examined individually, it is possible to see the diversity on the range of their likelihood to implement radical ideas. The range for Group C (the control group) shows the widest range between +0.4 and – 0.9. Of the 10 group leaders only three showed a correlation of greater than 0.5 (plus and minus) suggesting that only these three participants would actually act on their preference. Overall, there was a lack of confidence that participants would implement any ideas.

Although the groups looked similar in terms of size and composition, differences in the result could also be influenced by the relative maturity as a group. Group A was a relatively new group and struggling to raise revenue. Group B had a record of accomplishment in securing funding and Group C relied on a few, large industrial contracts. This will have had an impact on the people and their experience in generating ideas based on their experience. Group A was likely to be inexperienced in generating ideas for revenue, whereas Group B had in-depth experience in doing this. They were also likely to be tied to their traditional approach and less willing to adopt new ideas if comfortable with the existing approach. The results may have been different if the groups had selected differently. The commercial experience of group B when coupled with the business biomimetic models may have produced a better result. Group A left to their own devices without either management or business biomimetic models may have stayed floundering. Group C with industrial contracts may have produced different results. Such variables were not tested in the test case but do provide a valid challenge to the results. The mixing of the groups had been considered prior to the start of the experimental process. It was decided to keep people in their research groups as this both reflected their actual structure and because of the leadership bias in each group.

Difficult to implement ideas, or ones that are counter cultural should not be dismissed. Ideas that are uncomfortable to implement are likely to be the ones that will create step change. Those which are readily acceptable are more likely to generate incremental change. What is radical for some is seen as possible for others as has been shown in the difference between senior group members

General observations

Members of the groups were helpful and engaged in the test case. All the workshops have demonstrated high energy and a commitment to provide the best possible results. In terms of participation, there was a good attendance from the groups with 29 people in total taking part. There were 187 ideas generated which were grouped into 36 themes each theme having an average of 5.2 ideas. One of the models in the traditional business group generated 47 ideas. The Biomimetics and Traditional Management Groups generated the same number of themes (13), the control group slightly less (10).

In the survey the groups generally responded by saying that it was unlikely that they would implement radical themes. The groups believed that much of what was done today directly impacted the KPI's although all agreed that there was not a plan (strategy) to achieve the KPI's. All felt that the measures were a 'nice to have' and

not a real target. Generally, the groups felt that in terms of strategic thinking the themes generated by the workshops were not related to today's thinking. There was a feeling that there was a much closer link between the thinking generated at the workshop and the generation of radical ideas. It was unlikely that this strategic thinking would be taken forward.

Anything that was radical or challenged strategic thinking was unlikely to be implemented. This suggests a status quo unlikely to change. There were individual differences to this. In the workshop discussions each group identified an area (or areas) of significant weakness that currently were not been proactively addressed. The groups also identified a number of significant areas of strength that were not being proactively addressed. In contrast, all the groups generated a wide range of strategically challenging ideas. It was agreed that each of these was capable of having a positive impact on the performance results.

Chapter 6 The application of biomimetic models in industry using case studies

Case study method

As the initial hypothesis for the thesis came from the quest for businesses to continue to develop innovation techniques, it seemed appropriate to test a number of the models with industrial partners. It would indicate whether the models, when applied in a commercial environment, would be successful and would be a useful reference to know how well the biomimetic models would be received. The businesses participating in the case studies were customers of Thoughtcrew Limited and were paying for the research and supporting consulting. Their expectation was that the work would improve their business condition.

Six organisations agreed to take part in testing out a number of the models. The organisations were chosen because they would represent a broad range of different ‘businesses’ both in the private and public sectors. The testing of the models ranged from discussions with the senior management team to a full project which used biomimetics throughout.

Organisation	Description	Initial issue
Military policy group	Team of approximately 100 senior officers	Innovation
Health Insurance	A £3.2 billion turnover global business	Beating competition
Brewery	The largest global brewer by volume	Cost saving, process improvement
File storage	Global market leader	Business growth
Weapons supplier	Largest UK supplier	Innovation
Food and beverage	Top performing international brand	Product innovation

Table 30: Case study organisations and their key business issues

Whilst there could be no control in the approach to the case studies, a similar approach was taken with all organisations. The project was fully managed by the

author on behalf of the brewery covering the full cycle from initial request through to benefits realisation.

Military Policy Group

The doctrine and policy unit within the UK forces is responsible for the development of doctrine, policy and strategy. It is part of the military college and is staffed by senior officers from all three forces.

The challenges facing this group include many experienced by all types of business. They need to train and innovate for a changing role. There needs to be a greater emphasis on management training with leadership rotating on a two-year cycle. The group works across function, geographic and leadership boundaries. The processes are traditionally based and they are in a non-competitive environment.

The military seminar approach consisted of four steps. The first was an initial meeting with two senior officers, one from military intelligence and the other from the infantry. The central theme to the discussion was biomimetics and the approach the author was taking to biomimetics in business. During this session it was agreed that this topic would be relevant to the senior staff at the military college in Wiltshire.

It was suggested that the next step would be to meet with one of the key military suppliers. The reason for this was that the supplier was closely involved in both the human machine interface and innovation. At this subsequent meeting, the scope of a possible workshop was agreed and a review of the author's models identified with a number that could be used.

The seminar attracted 48 senior ranking officers from the three services. The seminar started with an introduction to the research area followed by a presentation on the biomimetic models. Three models were used, Poison Adaptors, Past Casting and MRS GREN. A discussion about the models and how they might apply to the work of the group was then facilitated.

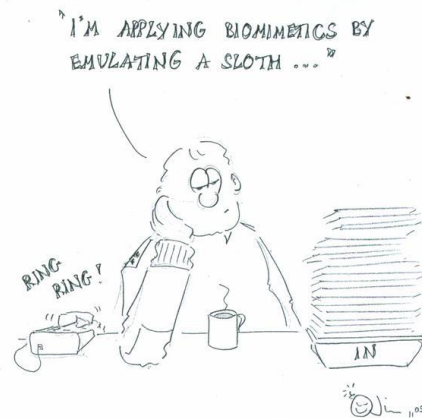


Figure 30: one of the delegates produced a cartoon capturing the subject

Discussion

Following a presentation on the research, the group broke out into an energised debate on biomimetics. There were two distinct responses to the research. The first was part of the group taking a literal approach to biology and comparing their behaviour to animal behaviour. Examples included comments such, as “are we a pack of gorillas?”, “do we follow each other like ants?” The other argument voiced was that biomimetics had a role to play as an analogy in developing innovating thinking. Figure 30 shows the response from one delegate at the meeting.

The room divided almost into two positions. This highlighted the possible ways of applying business biomimetics. Up until this point, the emphasis had taken an analogy approach; taking the biological systems and extracting it into the business context. This was one of the factors that led me to consider the two aspects of biomimetics, mimicry and analogy, as they may be applied to business problems. The seminar concluded with an invitation to attend future innovation sessions, as there could be a role for business biomimetics to play in their doctrine and policy development.

Health Insurance

This provider is a key player in the health insurance market. It is an international company recruiting experienced managers who are managing dispersed resources whilst working with an old infrastructure. The product is getting more expensive although the business is losing market share. Despite being a product centric organisation, there is a comprehensive leadership development programme in place. Because of this, the business delivers world class customer service.

Discussion

The health insurance industry is heavily regulated. Because of the nature of the business, it needs to comply with both medical legislation and insurance legislation. During a series of discussions, it emerged that one of the key challenges to this health insurance provider was gaining competitive advantage whilst staying compliant.

Following a briefing on the biomimetic models, it was agreed that the Poison Adaptor model might be a useful starting point. A meeting of the senior IT and analyst community was convened and the model explained. A lively discussion followed and the outcomes documented in meeting minutes. Based on the meeting discussion a follow up was scheduled with one of the regulatory authorities.

Work with the health insurance business spanned across a number of meetings culminating in a session being held with the IT function. Using the poison adaptor model the group determined that proposed legislative changes from the FSA¹¹ presented as consultative documents usually resulted in an approach by the business to mitigate the impact of the proposed changes. By applying the poison adaptor model the group agreed that their typical IT solutions were significantly over engineered for compliance. Based on this the business defined a number of enhanced changes to the legislation that had already been solved by the business but would put a significant strain on the competition.

The group had never considered approaching the FSA with their specification. The whole of the business had geared up to cope with the changing legislation. This proposed approach based on the poison adaptor model took the ‘poison’ of legislation and adapted it to work for the business whilst at the same time make it more toxic for the competition. This approach required a change in how the business operates and will need the process to work across more than just IT. The impact of this approach is that the competition needed to spend significantly more on their IT solution which would be a substantial drain on their key business resources.

¹¹ FSA is the Financial Services Authority <http://www.fsa.gov.uk/> accessed 16th June 2008

File storage

This client is a large multi-national company specialising in data warehousing. The strategy appears to be focussed on the short term and is sales rather than customer led. Some of the immediate challenges that it faces are that it is losing market share, has unhappy managers and has no obvious processes in place.

This was a workshop set up with twelve senior managers from across the business. The purpose of the workshop was to identify ideas to address their key challenges. The Past Casting model was chosen.

The workshop started with gaining agreement on the business challenge. There then followed an initial briefing on the model. Using the model concepts of taking constraints as a positive barrier to growth the group was split into groups of three and asked to identify one of the key businesses challenges.

The next step was to individually list as many items as they could in ten minutes that were attributes contributing to success in the area they had chosen. As a group, their items were discussed and a consolidated view was agreed which then they ranked as a top ten. With the top item being, in their view, that which contributed the most to the current success. This list was then put aside.

The groups were then asked to repeat the process identifying items that could be worsened to make the current situation less successful. Again this was done individually and then discussed as a group finally creating a consensus ranking

The groups were then asked to create a combined list. This list to contain the top three (of the ten items identified for improvement) from the first part of the workshop – with the top three from the second list (of the ten items that could worsen the situation). The groups now had a list of six items. At this point, the challenge of the model was applied. Looking at the list of items that had made the business successful to this point how many of these could be constraining the growth of the business going forward? The groups then discussed these and identified a number that could be reviewed to see if they were acting as constraints.

The groups then looked at the second three to see whether they were having a negative impact. Finally, an action list was created to review those items that, whilst they had been successful in the past might now be acting as constraints. The action was to see whether items from this consolidated list could be stopped, then evaluated to see whether this made a positive contribution to the original issue.

The possibility of applying business biomimetics to problems within this file storage operation had been discussed on a number of occasions. Up to this point, much of the work had been more education than application. The company decided that it would run a workshop at a commercial meeting to test out the possibilities. This meeting consisted of a mixture of commercial people, finance, contract management, general management and HR. Using the Past Casting model as the basis for the workshop the business focus was compliance and particularly complying with the Sarbanes Oxley Act (Wikipedia 2002). The reference is shown to provide a source of background information. A link to the actual Act is included in the references.

The workshop split into four groups of three. Each group then decided which business problem it would like to address. The selected problems were two groups of recruitment, retention and account management.

Before being exposed to the model, the groups initially spent time agreeing the scope and scale of the problem. This took longer than expected. The groups then identified all of the successes they could think of that made them successful. Each group identified the top three successes; these were based on their opinions as to what had contributed to the success of the topic they were reviewing.

Recruitment

For recruitment, there was much discussion about the positive aspects of the company. Although this did not help the groups generate specific successes for recruitment, it did provide reasons why someone might want to join the organisation. By focusing back on the past casting model to look at the specific recruitment strengths, the group identified a number of initiatives that were either ideas that had been thought of, but not tried, or ideas that had been thought of, but abandoned.

Working through the capabilities and attributes that contributed to the successes the business had in recruitment identified a number of ideas that could be implemented almost immediately back in the business. Without prompting, they also identified three ideas that they would stop as part of the casting process. The two groups that had selected recruitment went through a similar experience.

Retention

Initially the group started their discussion by looking at the reasons why people leave the business. This created an atmosphere of dejection in the group whilst each member of the group related their personal experiences about the reasons to leave. This covered a wide range of topics from pay, expenses, car policy, promotion prospects and location facilities. Encouraged to move back to the past casting model they started to pick through each of these areas and identify the successful aspects that could be taken forward. Once the group felt in a more positive frame of mind, it quickly identified over ten ideas that it felt would be worth focusing on back in the business. They also identified personal actions that would help their own development.

Eight of the ten ideas identified by the group had not been used before in earnest by the business to aid retention of staff. They felt that this was a great breakthrough in their thinking and felt energised by the biomimetic process, as it had given them an opportunity to step away from the problem and then manage to address it. They were keen to take the ideas forward to be adopted by the rest of the management team.

Account management

This group found it easier to discuss what was not working in account management rather than focus on the successes. Bringing the discussion back to successes was challenging as members of the group had not had positive experiences with those responsible for account management in the past. A typical example was that of a salesperson that had had little to do with the client but then was claiming a significant commission on sales achieved whilst the contract manager actually did the work of managing the customer thus creating an atmosphere of resentment between salesperson and contract manager.

This group identified a number of areas that they had traditionally felt was the domain of the sales team. After prompting, they discussed the possibility of taking more control of these aspects. A typical example would be the discussion of a new business

opportunity with the customer. In the past, this would have automatically passed to the sales team. Now the group were discussing whether their relationship with the customer would in fact be best used in developing new business.

Discussion

Like many of the case studies examples presented in this thesis, the groups struggled with defining the initial problem statement. The file storage company exhibited typical behaviour in that it tended to know the answer to the problem long before it had firmly established what the problem was. This could be best described as 'a results before hypothesis' approach.

One other aspect that was common to each of the groups was the tendency to focus on the areas that had either not worked, or would not work (their opinion). This was coupled with a tendency to jump to the solution before the problem had been fully defined. In general, there was no evidence that any of the groups had set meaningful performance measures so they could not substantiate what was or was not working.

The past casting model provided a way in which they could discuss these typical business problems in a way that focused on success and how the constraints today were based on the successes of the past. The idea of recycling was very useful as it allowed the discussion to focus on aspects of success rather than the whole of success in any particular area.

Many found it liberating to be able to identify aspects of their current business strategy that were not appropriate to the objectives they had set and to decide, as a group that they would stop these activities. The results of the past casting approach demonstrated for the file storage company that there were a mixture of constraints and ways of working that were simply based on past behaviour. This past behaviour may not necessarily have been successful in the past but it had been embedded in the current processes and approached. When challenged by the past casting model it became clear that these constraints were actually hurting the business.

At the end of the session, each group had identified a number of ideas that they intended implementing in the business. They had also identified a number of areas that they would want to investigate further. Most of these were concerned with ideas

that they should stop doing. In observing the group it was interesting to note the high degree of enthusiasm achieved once they had moved to successes and new ideas for future successes. Unlike management workshops that I have experienced in the past; rather than glad they had finished, the groups were glad they were about to start.

Those that attended the workshop were sent a follow up request

“Can you please offer a brief update of anything you have changed in the way you do your job or the way things are done at your site(s) based on the session?

You were asked to think outside of your comfort zone and come up with ways that you could become more successful by changing something that you already do well. You were required to write these down at the meeting and then go away and see if you could put them in to practice.

Please provide feedback on this in the box below.”

Each group provided a response that captured their opinion as to the impact the session had on their part of the business. Some examples of the responses are presented below.

“Although it’s been an interesting lesson of personal interest, I have applied some of what I’ve learnt at work. During recent months, staff had been raising their concerns regarding pay, bonuses, conditions and absence. So I looked at things that we were (recently) doing well such as holding regular staff meetings, nominating staff for awards, recognizing the efforts of staff during busy periods, and general interaction.”

“After making use of this methodology, we were to discover that management felt more responsible for their failures and a new found desire to change was ignited. This resulted in management delivering our objectives and although staff still have issues with pay and bonuses, absence is beginning to improve. Staff are more engaged with management and there is detectably a greater morale within the team. They now also appreciate that their concerns are being listened to and are evidently much happier at work.”

“I’m sure that reflection of biomimetics will be of benefit for me in and out of the workplace”

“It has given me an insight into how better to communicate during appraisals, team briefings etc and not to just assume that others know what is going on even if there is nothing to communicate.”

“in future, we need to be more prudent and either give ourselves a longer phasing and or put in place a more intensive training schedule.

“In this I believe we continually “look outside the box”.

“One area admittedly that we need to do better is that we could have produced more and better workflow diagrams which would have helped in the training and ongoing monitoring of the processes”

“This provides follow up evidence that the intervention with business biomimetics had an impact on the business.”

Weapons supplier

The weapons supplier is a well-known global player with significant interests in both the US and Europe. They appear to be a product rather than customer centric organisation that need to demonstrate constant innovation in the delivery of their very large, complex projects. There appears to be a lack of integration between the commercial and technical aspects of the company.

This meeting was a spin out from the military workshop. The supplier contacts at the original workshop suggested meeting with the senior directors of the business to see whether this approach merited inclusion into their business strategy

The meeting covered the background to the models, the models and suggested applications to the weapons business and markets. The meeting concluded with a discussion on the merits of the approach and agreed the next steps. These were then documented. Rather than a structured workshop, the interaction with this company was via a number of conversations across three key areas; commercial, development and human systems.

Commercial

This was the least responsive aspect with a conclusion that the business biomimetics approach was too far from their current thinking. This coupled with pressures on their overall business structure meant that the focus was not available.

Development

The development group already have a healthy line of research and development underway based on the application of biomimetics. Whilst interested in the business biomimetic aspects they felt that their overall approach was in product development.

Human systems

The conversation about the application of business biomimetics started with the head of human systems. This part of the company is responsible for defining the interaction between humans and the technology that is developed. It ranges from the physical ergonomics through to the behavioural science. During the discussions it became clear that the real opportunity was in getting breakthrough thinking. Whilst the topic has not been taken further at the weapons supplier, it did lead to an introduction to the Army discipline and doctrine group.

Discussion

I was disappointed that this business seemed closed to the idea of applying business biomimetics particularly when my perception of the business was that it was at the leading edge of research and development. I recognised that they were under pressure from a number of significant areas and that this might preclude looking at something new. My approach to this company had been early on in my own research and now with the benefit of more practical experience in the application of business biomimetics, I realise that this would have been a perfect time from them to break through their thinking barriers. On the positive side, I did get an introduction to the central policy unit of the Army. My intention is to re-visit the weapons supplier later, presenting the evidence I have gathered from a range of organisations. This case study also demonstrates that not everyone is prepared to engage with the business biomimetic idea. It potentially suggests that there is an optimal company profile. Identifying this profile is one area worth further investigation.

Food & Beverage

This particular business was primarily focused on product innovation and packaging design. They have well known and well loved global brands and their current research and development was centred on chemistry.

They already had a significant amount of exposure and experience in looking at the broader application of biomimetics to their business so this meant that the audience

were then at a different level of education in terms of biomimetics compared to the other case studies.

The meeting consisted of senior managers who were each engaged in an aspect of product or packaging development. The focus of the meeting concentrated on whether or not the biomimetic model approach could be adopted as part of their innovation process.

The author presented the business issues and described how these had then been isolated and suitable biological systems chosen to act as analogies. Examples from the Test Case and other case studies were explored and the possible application to the internal innovation process discussed. There followed a discussion about the strengths and weaknesses of the approach and possible ways forward. The meeting concluded with a set of agreed next steps.

As had been experienced with the other businesses there was a polarisation of responses. The two typical responses were the group that looked at the work as a simple set of tools and the group that felt that the work presented could offer a new way of thinking about innovation, particularly as it applied to packaging design.

Discussion

The preparation had been aimed at giving an overview of the research to two of the company executives however with the expanded group, the discussion turned into a formal presentation. There were a number of interesting outputs from the meeting and the entire group felt that the business biomimetics models had a role to play in innovation. Everyone agreed that the models could be used as part of the innovation toolkit. A number of the group felt that business biomimetics offered more merely a toolkit in terms of its potential which could be used to change the innovation agenda. It was agreed that both of these aspects would be explored at future meetings.

Brewery

This well-known brewery was operating in a decreasing market with costs tied up in the supply chain. There appeared to be a lack of integration between the different functions of the business and it was recognised that there was a need to change how the sales operation was working. They seemed to be working independently from other departments making them unaware of their internal environment. In addition to

this, the sales team had become so driven by the need for volume sales that they had lost touch with their external environment and needed to build better relationships with customers.

The span of the project was from initiation through to post implementation and the biomimetic models were used as a component of the project. The author was the project advisor from inception through to post implementation.

Initiation

The project was initiated by the question of why there was a difference between the volume of sales claimed by the sales team and the volume of beer leaving the brewery.

Data gathering

Based on the question, an analysis plan was created. The first step was to identify the processes that were involved in beer ordering and delivery including gathering the performance data for the processes and for the outcomes of the processes. Key people were interviewed and a number of workshops were used to pull together the detail of how the processes worked and how the key activities were linked. This produced an end-to-end process map and the supporting performance data.

This work identified the *scope ideas*. This included those ideas that already existed, had been tried before or were already planned.

Analysis

Having identified the processes and the performance data it was then possible to analyse this to discover possible causes of the difference. This analysis process was completed in two stages. Firstly, the author reviewed the data and created a short list of possible areas to investigate then a group of managers from all the departments involved were pulled together in a workshop.

The workshop then followed the process from start to finish, validating the author's short list and adding in additional issues they felt were also important.

This work identified the *management ideas*, i.e. those ideas that were generated using the existing management skills and experience, now that a specific focus had been given to the problem.

Problem identification

Armed with a list of problems, as perceived by the group of managers, another workshop was run to challenge the difference between symptoms experienced and the root causes of the problems. This workshop then produced a documented list of problems ranging from performance data through to the management of the supply chain

Biomimetics intervention

At a follow on workshop the management and project team were introduced to the concept of biomimetics and how that might work with problem solving. The workshop started with a recap on the root cause of the problems and then went on to explain problem solving using the TRIZ method (Altshuller 1998). The explanation showed how it is possible to extract the engineering principles from TRIZ and use these principles as biological ones (Vincent, Bogatyrev et al. 2005). How these could be used to provide solutions to the problems was of interest but even more so was to achieve this using lower energy. The energy in this case could be equated to cash.

Acquainted with the possibility of using biology, the teams then explored the biomimetic models, specifically the Past Casting. Using the model as a catalyst to thinking, four groups were formed to think through possible solutions to the problems using critical analysis similar to that used by Ulrica (Ulrica 2001) to help with the process.

Having identified a number of potential solutions they were then evaluated using an hybrid set of criteria (Rumelt 1995),(Johnson and Scholes 1993) .

The projects were classified into p (process), r (rule) and c (conversation). Using the following convention, p was a change in the process which could be new, changed or deleted, r meant a change in the rules of running the business, new, changed or stopped and c referred to a change in conversations, either a new, changed or stopped conversation. In this context, a conversation was any interaction between people. This workshop generated the *innovation ideas*

Having identified the solutions a project team was created to implement the chosen solutions. This team followed standard project management methods to identify the gap in processes, governance, organisation, strategy and technology. A new business design was created and using the above gaps as a basis, an implementation plan was created. The project team delivered the plan and the performance measures were gathered.

Evaluation

On completion of the project the initial business issue was revisited and a report created by the project team noting the changes in performance.

Brewery: Results

The work with the brewery lasted for over a year. This provided an opportunity not only to assess the ideas generated but also the adoption of the ideas, their integration into the solution and the overall outcomes. Unlike the other case studies examples, the brewery project provided the opportunity to closely simulate the design aspects of the earlier test case by including a level of base lining (control), business and biomimetic interventions.

The problem was initially presented as a difference in the volume between the brewery and the sales volume claimed by the distribution channel. This problem had existed for some time and the brewery had made a number of unsuccessful attempts to address the issue.

At the start of the project, it was established that the issue was complex. It was caused by problems with process design, strategy, customer management, organisation design, process ownership, inappropriate key performance indicators and a lack of functional integration. It was agreed to take a three-step approach to determine a suitable approach to solving the problem. This also turned out to be a very effective way of getting stakeholder engagement when many had seen earlier attempts to resolve the problem fail. (Winstanley 1995)

The first step was to run a workshop with people from across all of the functions involved with the process. The purpose of this workshop was to identify all the ideas that were currently in the consciousness of the business. The second workshop then

focused on traditional management models with a specific emphasis on the value chain (Porter 1985). The final workshop used the Past Casting model in a wider context of problem solving¹² The numbers of ideas produced by each workshop are shown in Table 31.

Workshop	Number of ideas
Scope – existing ideas	13
Management	19
Biomimetic	33

Table 31: Differences in number of ideas for the brewery

The brewery was asked to subjectively assess ideas that were common across all of the workshops. This was done in an attempt to acknowledge the existing ideas and thereby identify new or different ideas. This produced those ideas that were unique to the management workshop and those that were unique to the biomimetic workshop. There were also eight ideas from the scope workshop that were not identified in either of the other two workshops.

Workshop	Unique ideas
Scope – existing ideas	8
Management	17
Biomimetic	27

Table 32: Number of ideas for the brewery at each stage showing biomimetics was the highest

12 Professor Julian Vincent, The University of Bath, presented a session on problem solving using TRIZ principles

The ideas generated at the biomimetic workshop were evaluated against two strategic choice frameworks (Rumelt 1995) and (Johnson and Scholes 1993). This evaluation generated the following results from the biomimetic ideas. Twelve ideas suggested changes to current business rules, eighteen suggested changes to process and three suggested changes to the conversations and behaviours of the management team. Specifically, eight ideas would mean changes in the brand installation process and a further four would mean changes for the customer. In terms of governance, they would need six changes in credit control, six changes in health and safety checks and nine changes in planning and data visibility. Of the 33 ideas, sixteen would help reduce the process time from 34 days to possibly two. Twelve of these were relatively quick to implement although they would take a significant amount of effort to change the way of working in the business so that they could be done quickly.

Of particular interest to the brewery was that twenty-four of the ideas would potentially contribute to the long term value of the business and that twenty- three of the ideas would provide a long term competitive advantage. Twenty -seven were seen as being feasible with twenty- three believed to be acceptable to the business.

The ideas were then taken forward into a design for the project which was subsequently implemented. Key performance indicators had been agreed and measured at the start. Three of the results were directly attributed, by the brewery, to the intervention that included the use of biomimetic models. The time taken in running the process reduced from an average of 34 days to 14 days. Costs had decreased by £1.2 million and projected sales increased by £18 million.

Finally the team identified the ideas that had been included in the implemented solution which are shown in Table 33

Workshop	Number of ideas
Scope – existing ideas	6
Management	10
Biomimetic	25

Table 33: Number ideas that were actually implemented by the brewery

Discussion

The difference in ideas generated between the first and the third workshop showed a marked increase. It could be argued that the group were becoming better skilled at idea generation. There is also the question of the ideas that were identified in the scope workshop that did not appear in a subsequent workshop. This was possibly a case of active filtering or dismissing of ideas that had already been thought of. Ideas that were identified in the subsequent two workshops were described differently but were sufficiently similar to be classified as being the same.

What was more interesting was the number of ideas that were incorporated into the final implemented design. A significant number from the biomimetic workshop were incorporated in almost their original form. The project has also identified two future stages which aim to include all but two of the 33 original ideas.

The evaluation at the biomimetic (the third) workshop results indicated a number of key business areas that could be the immediate focus for the management teams. Vital to underpinning an end-to-end process design would be an integrated planning and information system. It would also require ownership of the whole experience with clear accountability for supply chain partnership; internally and externally. Multi-skilling the team and clear business leadership would be required. This would necessitate the creation of new leadership roles that would span a number of functions. Clear integration of the process into the brand value would be required if any solution was to be embraced by the key stakeholders.

The biomimetic workshop brought a new level of debate and discussion that had not been held before. Key direction for ownership, leadership, design and infrastructure played a hugely important role in pushing the business forward.

The client was extremely pleased with the result and decided immediately to go on to the next phase of the project. This felt to be a key measure of success. This project had failed a number of times before in the business and it would seem that accepting all other factors as being equal the noticeable variant was the application of biomimetics and the positive impact that it had on the participants.

Case studies Results

Due to the variability between each of the situations examined, it was not possible to manage the case studies in the same way as a controlled test case. There was a degree of commonality which can be summarised as managers grappling with a significant business issue. In each example, the biomimetics intervention had an impact on the people who took part. Initially the important result seemed to be to analyse the number of ideas generated and the differences between the number of ideas, their quality and their 'implementability'. During the course of the case studies, my view has changed.

I was looking for a logical change in the outputs from each company examined and was hoping to demonstrate that the business biomimetic models created a fresh set of ideas. Whilst this was the case it would appear that, the benefits are wider and provide a richer resource to the business community. It is possible to look at the business biomimetic models as a tangible item to add to the manager's toolkit which is something to be used in a workshop or other group setting to help facilitate the process or conversation of the group. This is evidence that biomimetics can provide a boost in business performance. It also provides the principles by which the research can be developed further providing two channels, business biomimetic tools and a novel way of approaching innovation.

Use of the models in the case studies

Not all of the models developed during the thesis were fully explored during the Test Case or case studies. This is because, whilst eight biomimetic models were initially developed, only three were used when models were selected at random by each group of the test case. The case study models were selected based on the problem presented by the business therefore the most appropriate model for a particular issue was used. At this stage of development the models usage is represented in the Table 34.

Model	Test Case	Healthcare	Brewer	File Mgt	Military	Weapons supplier	Food & Beverage
MRS GREN	✓				✓		
Past Casting			✓	✓			✓
Poison Adaptors		✓				✓	✓
Alternation of Generations							✓
Life in Two stages						✓	
Symbiosis	✓	✓					
Two hosts				✓			✓
Flocking	✓		✓				

Table 34: Summary of the business biomimetic models used in the Test Case and case studies

Summary of the results

The results from both the Test Case and the case studies clearly demonstrate an impact. The development of business biomimetic models applied to the challenge of improving the position generated new ideas. Those ideas generated by the application of the business biomimetic models had a greater impact in both the Journals and Esteem measures. Esteem idea generation was significantly higher and indicates a particularly useful application for the approach in sustainability.

Not all of the models have been used extensively in either the Test Case or the case studies. This is not a weakness in the design as the approach was to demonstrate the effectiveness of the business biomimetic approach. Further evidence is provided by the brewery case study where the business biomimetic intervention generated a measureable sales increase and a cost reduction. The business biomimetics are being used to solve problems that business have struggled with using traditional models.

The brewery case covered the whole project cycle from inception through to implementation and one of the key outcomes was the benefit of developing joined up strategic thinking in the design phase of the project. There was also a significant increase in the number of ideas once the biomimetic models had been applied. This suggests that the use of the models can be additive. One other aspect to consider was the behavioural changes created in bringing the different participants together. As seems typical in large organisations the individuals worked in functional and departmental silos (Sy and Côté 2004). It could also be argued that by taking a system-wide approach using biomimetics this reduced the organisational risk, again associated with silo thinking (Liebenberg and Hoyt 2003). It was therefore a novel and unique experience to be working together on the same problem. Unlike the Test Case design where the biomimetic models were compared with the control and business models, in the brewery case the models were applied sequentially after the control (or baseline) and the application of business models. As it is likely that many organisations will have a degree of formal management training then this is a typical representation of what applying, the models in the ‘real world’ will be like.

In file storage, the real benefit of using the business biomimetic models was in bringing together a cross-functional team. The groups initially struggled with the creation of the original problem statement however; The Past Casting model was useful as it flushed out the positive side of thinking, focusing on what they did well.

When the biomimetic models have been used, this seems to generate a positive environment for the participants and therefore is more likely to lead to positive idea generation.

Chapter 7 Inventing the Infinity Context Free Process

Taking particular technique and applying to a new area

This creation of a new approach to the application of biomimetics is evidence of a unique contribution to the body of knowledge in management science and the field of biomimetics. The impact for management science is that the research created a new suite of tools and a method to develop more tools in the future. The impact for the field of biomimetics is that it provided a new management approach that provides a new commercial application. In developing the models, the identification of clear evaluation criteria has been shown to be essential and one which was welcomed by the participants in the research. The process used to develop the business biomimetic models emerged during the thesis and is presented below as a further contribution to knowledge.

I have called this the Infinity Context Free Process model. Using the word infinity to represent a continuous loop between biology and business. It is not meant in the mathematical sense, as there will be a limit to both the number of business issues and the biological systems. Context free points to the core of the process where the translation between business and biology is made, in either direction.

The development of a business biomimetic process: the Infinity context-free process model

There were two starting points in this research. The first was nature and its biological systems and the second was industry with its business systems and issues. To test the hypothesis that biological systems could be used for solving business problems it was necessary to develop a way of translating between the two. The key to this translation was to make the relationship context-free. In developing the models to test the hypothesis, a business biomimetic process was created. Initially the process developed as a linear relationship starting with the significant business issues, searching for biological systems that were similar. Once identified the translation step was done by creating a PowerPoint slide that could be used to explain the new biomimetic model. In creating these models to test the hypothesis, a new process evolved that can be used to generate further models.

It has the advantage that not only can this be used to create biomimetics models from business issues; it can also be used by starting at the biological point and looking for 'new' business issues. I have called this the Infinity Context Free Model. Whilst the Infinity Context Free Model was developed because of carrying out the test case work, it has been included in the conclusion as it was developed as a consequence to the biomimetic model development. The process will become the core of the proposed consulting offer.

The working of the Infinity Context Free Process Model

In developing the biomimetic models, a requirement emerged to provide a construct for the models. In exploring the new models, it became apparent that the models themselves were part of a bigger process. This process created a way in which to describe the transition from nature to business and from business to nature through a context-free phase. The following protocol describes the development of this process. Using the existing experience in biomimetic application, the development of this framework started with nature, looking for a product opportunity. The framework then evolved through seven steps.

Step 1

Moving from the biological system to the product



At this step, biological systems are observed and the attributes of the system are identified. These attributes include structure, substance, space, information, time and energy. Extraction of this information leads to the design and fabrication of a product based on mimicking the observation in nature therefore using both the biologist and the engineer.

Step 2

Moving from the biological system to the business system



This approach was then further refined to broaden the product thinking to business systems. The opportunity to apply attributes from a biological system could be used to engineer a business system that addresses a specific issue.

Step 3

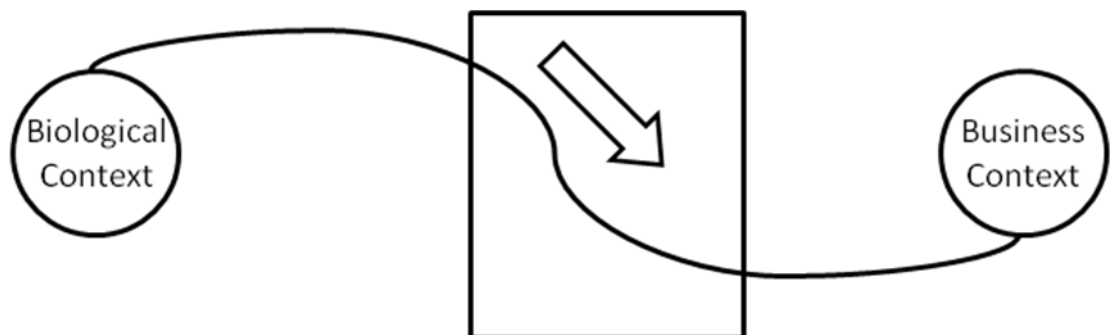
Moving from the biological context to the business context



At this point, the biological system has been examined in the context of the biology and the business system has been examined in the context of the business. Both of these present paradigms of thinking could lock the creativity into the existing context. The model seeks to break out from this constraint by understanding and changing the context.

Step 4

Translation from biological context to business context through the context free zone



Creating a biomimetic model gives the active translation of things and processes from one context to another requiring a transition through a context-free stage. This carries through the processes and the function or attributes.

Step 5

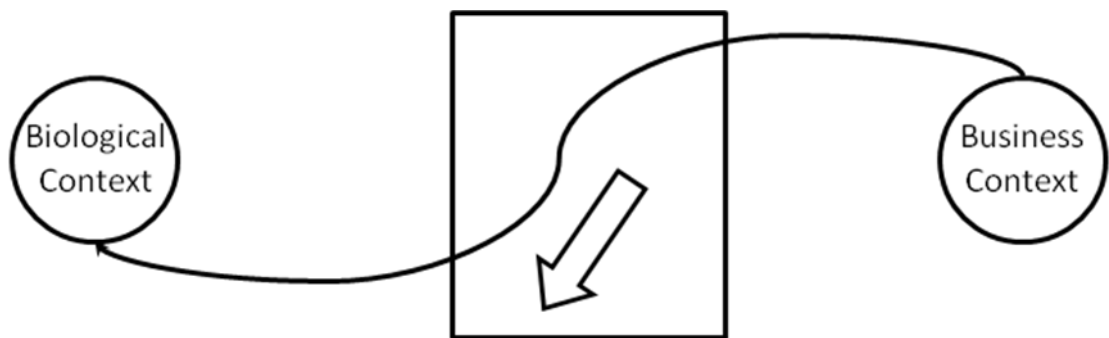
Translation from the business context to the biological context through the context free zone



The process is then reversed which means that starting with the business context, the search is then on for the biological context.

Step 6

Translation of the business context into the biological context through the context free zone



As before the context, free step allows translation between the business system and the biological system thus taking the business complexity and building the search criteria for the biological system.

Step 7

Completion of the model which shows the infinity process aligning biological context with business context.

Two flows exist in this infinity process. The first starts with the business context and extracts the business issue. This is then translated into the search criteria for the biological system. The biological context is then identified and a business biomimetic model is created. The model is then applied to the business issue to provide a context free approach to thinking through potential ideas. Feedback via the business context allows improvements to be made in issue definition and biomimetic design and selection.

The second flow is from the biological context. This identified biological biomimetic models which can then be applied through the context free translation into a wider business context. The validity of the ideas generated, opportunities identified and

subsequently problems solved provide a feedback loop back through issues presented from the business context.

Running both flows simultaneously as shown in Figure 31, allows the identification of solutions to both known and unknown problems and opportunities thus following an infinite loop of discovery and refinement. This can be initiated from the biological or business context.

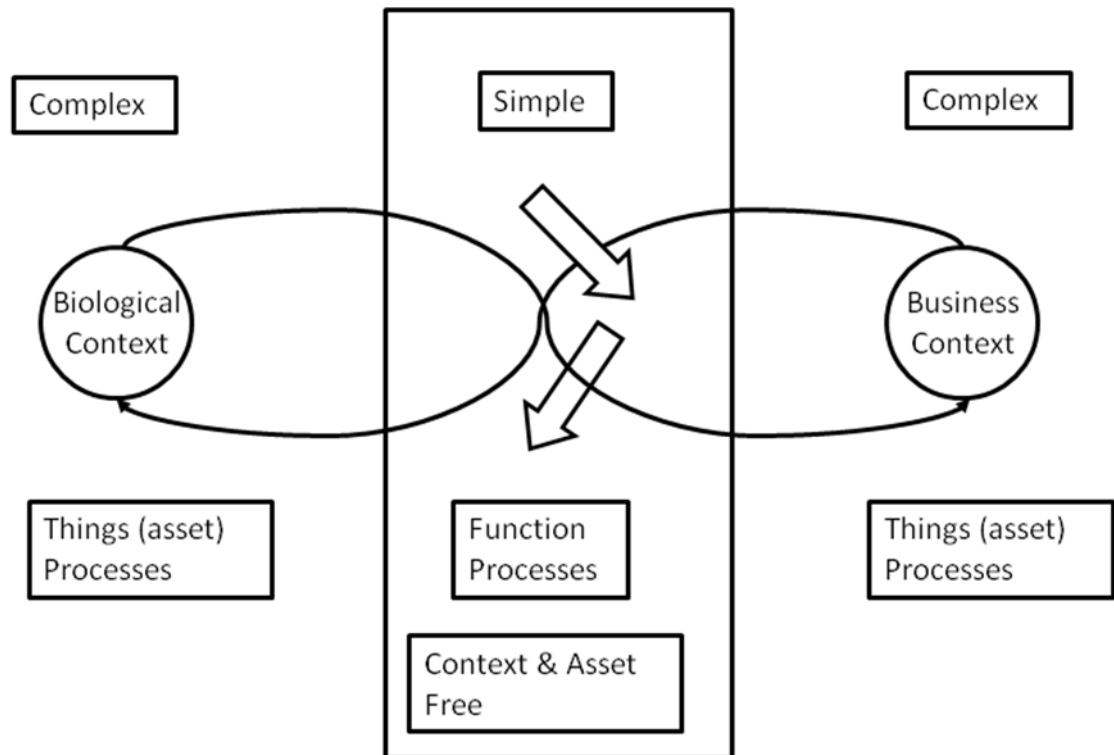


Figure 31: Infinity Context Free Process (ICFP)

The next stage in developing the model is to make it accessible to businesses so that they can either build it into their existing processes or add it in as a new process.

Work has already started in developing a set of flash cards that can be used to facilitate the process. This approach to shared abstraction (see page 184) has proved useful in both the test case and the case studies.

Chapter 8 Further developments in Biomimetics

This chapter explores the wider context of business biomimetics and how it may be related to other approaches such as traditional business models and problem solving approaches such as TRIZ. It also describes how the new approach can be incorporated into the current management theories and then applied in change management and consulting. It shows how the new business biomimetic approach could be incorporated into management teaching by demonstrating the universality of the models. To demonstrate this, a comprehensive matrix has been produced identifying the possible relationships between MRS GREN and the TRIZ principles. As yet the attributes of each model have not been analysed to see if they integrate in any way and this is one of the proposed actions following the PhD.

A number of suggestions for further development are explored. Practical application aspects are considered such as the need to properly define the initial problem and to have an agreed set of measures. The practical application of business biomimetics also includes the opportunities for commercial development for use in a wide range of business applications from culture change to business transformation. The chapter starts by setting the context that was developing whilst the PhD was progressing.

Opportunities to share the business biomimetic ideas

There have been two biomimetic initiatives that I have been involved in since beginning the PhD which were a technology mission and involvement in the Biokon network. My involvement indicates the credibility behind the business biomimetic approach. Further details are provided in Appendix F.

Biomimetics, the models, business and the environment

Both the Mission and the relationship with Biokon highlighted the continual focus on the application of biomimetics to engineering challenges. Biokon International has started a new working party for business biomimetics which is chaired by the author, demonstrating that there is at least the willingness to listen and explore this new approach. Business biomimetics is now being discussed within the research community and a growing number of businesses attracted to the Biokon brand. This, coupled with the growing number of customer case studies, brings a much broader scope for development to include product development, strategy, change and performance in the market environment.

The opportunity to broaden the scope to include the business environment also brings fresh insight into the applicability of the biomimetic approach. This would mean that the environment, corporate social responsibility, sustainability and climate change all become viable areas to explore further. This suggests that the business biomimetic models can be either embedded or blended with environmental models. Symbiosis and the Two Hosted Parasite model appear to be useful here. Work by Dobson and Carper suggest that there is a measurable impact of climate change on the relationship between parasites and their hosts (Dobson and Carper 1992). The consideration of micro and macroparasitism coupled with the Two Hosted model suggests an opportunity to define two potential business strategies from the same model. The key parameters seem to be size and lifespan, system and a critical business concern.

Parasitism is an example that has immediate applicability, suggesting that all competitors are parasites. Mistletoe is a hemi-parasite which draws its nutrition from the host tree (typically an apple tree in the UK). The seeds must be transported by certain birds (Mistlethrush and Blackcap) and the separate male and female flowers attract only a limited number of insects. There are about 1500 species of mistletoe globally. Propagation is mainly by seeds which are deposited on living host tissue (tree branches) in bird faeces. They are particularly attracted to honey/nectar eating birds which hover over the branches whilst extracting the nectar. This understanding gives two new avenues of research. The first builds on the earlier interconnectedness argument where there is now a clear link between the actions of parasites and the environment. The second is the role of hemi-parasites and their specificity in an environment. This opens up an opportunity to build a new set of business biomimetic models based on the role of parasitism as a sub set of the symbiosis model. This model or models would also have an overlay of environmental dynamics giving the possibility of creating a hemi-parasite like strategy or in identifying new competitors that are exhibiting these characteristics.

This approach raises the question whether other parasitic model would produce a different result. With the limited scanning of biological systems available, it is possible to suggest that different models could provide a different result. At the higher level when the concept of Symbiosis is being discussed then the results will be similar. When the specific of a particular biological system are being evaluated then the result may change. This is an area for further study.

On the Origin of Business

On the Origin of Species (Darwin 1859; Darwin 1998) doesn't actually help determine the origin of all species; instead it presents an argument to explain the

variety of species that exist today and gives some insight into the process that led to this. To explain the interrelatedness of all species Darwin produces a tree of life. From this, it is possible to suggest that the Origin of Business (and possibly the tree of business) could be developed. There are a number of ways in which this parallel could be used. Good examples include “principles of destruction” and “struggle for existence”, which work for nature and business. This way of thinking could also lead to further analysis of inherited characteristics and the application of variance; “how could the wolf become thinner and faster than the parents?” Challenges about the speed of evolution could be answered with examples from pigeons and dogs where dramatic changes have happened in a time that is representative of some of the longer-term brands that exist today. There is a good case to discuss natural selection and extinction which combines the concept of natural destruction through downsizing and natural selection driven by market forces.

In taking this idea forward, the key question to answer would be to know what is being favourably selected in nature; selection can be traced back to DNA. The DNA of a business is more difficult to define. It could be the explicit knowledge that is held in various data sources within the business or the tacit knowledge held by the people, which can be inside and outside the business. It may also include the relationship between the people and the processes or the culture of the business. This idea of DNA could be combined with the culture web (Johnson 2004) to become part of the culture audit typically carried out before a major business change. It would also be possible to use this to introduce the notion of random event into the discussion about the future: Thus linking culture, change, DNA and evolution. The subject of evolution has emerged during a number of the discussions, particularly in the case study results. From a business point of view, it would appear that selection is the key. In the introduction, mergers and acquisitions were discussed and a parallel was drawn between breeders creating new breeds and mergers and acquisitions. At a crude level, such mergers are the interbreeding of different species creating a new super species. Empirical evidence shows that many fail and in a number of cases both of the original companies are significantly worse off. According to a survey by PriceWaterhouse Coopers as many as 75% of mergers and acquisitions fail (Turner 2000). Whilst there is a growing understanding of the reasons for failure perhaps, a better way would be to build a biomimetic model based on selection then look for ways to apply this to improve the outcomes of such change. This is particularly important if businesses are to be fit for the future.

Of particular interest is the correlation aspects of the laws of variation (Darwin 1859), where one selected aspect has a direct correlation on another aspect. This, coupled with the concept of sub breed selection rather than cross breed selection, would be a

challenging starting point for a selection/variation model which could be applied in an M&A situation. This could also be coupled with the Past Casting model to show how growth could be achieved by 'Past Casting', 'Selection Variation' or both.

Lamarckism for management

It is generally accepted amongst the evolutionary biology community that the only credible alternative to Darwin's theory is that proposed by Lamarck (Lamarck 1809). However it is acknowledged that this theory has been largely rejected by the biology community (Charlesworth 2008). There is no evidence to support the argument that developments in the parent are passed onto the offspring. It therefore seems impossible that information can be coded into the DNA of individuals and passed down the generations¹³. There are, of course, mutations that could theoretically lead to the creation of a trait however when the statistics of Mendelian genetics (Mendel 1865; Blumberg 1996) are considered it seems unlikely that this would happen.

Businesses on the other hand are different. It is possible that the Lamarckian approach may apply. If we consider the knowledge built up by a business appears to be passed on in a mainly tacit way (Grant 2002), then it is feasible that attributes of the parent are passed onto the offspring. This is a simplified view as there is not a way to make a clear distinction between generations and it is possible to argue that many overlapping generations are in existence at any point. The basic premise builds on the behavioural aspects of Lamarck's work which states that behaviour builds capability.

This approach could also be used to explain the "spontaneous generation of new forms" (Lamarck 1984) as witnessed in the Dot Com explosion of the early 2000's. Rather than the gradual increase seen in a number of businesses (the equivalent of stretching the giraffe's neck) here, we saw a dramatic creation of new businesses. By approaching business from a biology perspective, it is apparent that both the Darwin and the Lamarck approaches are potentially applicable. This evolutionary business could lead to further discoveries on business survival. So far, what appears to emerge from this discussion is that information is central to the evolution debate and its application.

¹³ There is discussion that there is some transmission of information from cytoplasm to cytoplasm which doesn't rely solely on nuclear DNA

Natural intelligence

Decision-making is an area for most businesses that has varying degrees of information precision. In a number of cases decisions appear to be taken with little or no information (Simon 1999). This ‘bounded rationality’ suggest that decision making is limited by the amount and quality of information, the time available and the information processing ability of the person. Simon proposed two types of decision maker, those that are maximizers who aim to maximise the performance across all variables and satisficers who go for just good enough. The maximisers are obscured by a mass of data that may not necessarily be relevant to the issue being addressed. Whereas the satisficers tend to follow, the rule of nature and the results show that they achieve a better overall performance. Earlier when the challenges of problem definition were discussed, the real issue was the lack of consistency in information gathering and analysis. There are differences between how we solve problems and how the rest of nature solves problems as shown in the work comparing human technology solutions and natural solutions. (Vincent, Bogatyreva et al. 2005). Bees have a structured approach to information gathering. They sweep in equal spheres at a given distance from each other in a double layer to get the best ‘harvesting’ of wax and honey (Swammerdam 2002). There is an opportunity for business modelling that could be based on observations in natural systems. The multi-sensory hairs found on the spider’s leg provide insight into the way a complex management consultancy could work and this type of thinking could provide “breakthrough for the next big thing in consulting” (Walker 2009)¹⁴

As the level of interconnectedness emerged during the thesis I have started to map out the relationships, the type of relationship and the way the models could potentially interact an example is shown in Figure 32. What this shows is that one species; a plant in this case, can call for a predator that feeds on the plant predator.

¹⁴ Phil Walker who was the Chief Operating Officer at Cap Gemini in the UK made this comment after a workshop based around ‘creepy crawlies’ at the Natural History Museum, London

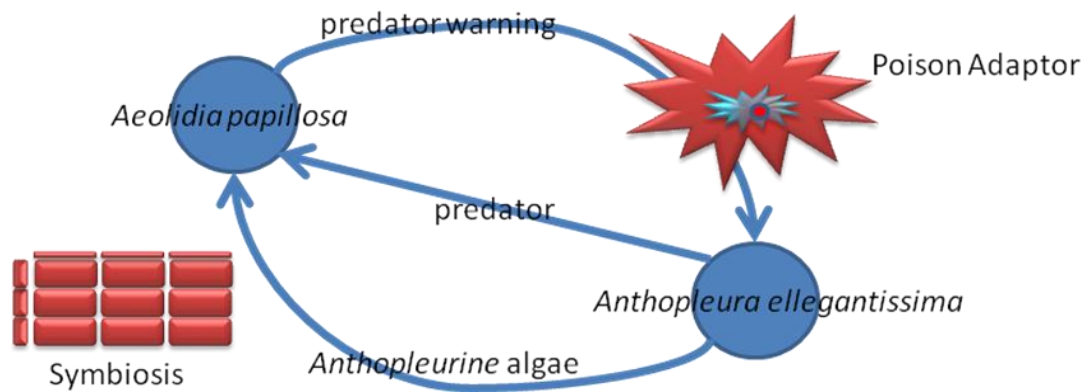


Figure 32: The interconnectedness of systems showing how the models can be used together.

Figure 32 shows the Sea Slug (*Aeolidia papillosa*) ingests anthopleurine as a consequence of eating the anemone *Anthopleura elegantissima* which triggers *A. papillosa* to move away – a poison adaptor. Interconnectedness is a key element of biological systems. No one system exists in isolation from other systems. Businesses often exhibit behaviours that suggest they believe they are separate. Observable behaviours include leadership meetings which focus only on internal aspects of the business however, when the importance of customers, suppliers and competitors are considered; the interconnectedness becomes all too apparent. Those which fail to take account of this interconnectedness often perform badly and eventually fail. Recent examples in the UK include the link between subprime mortgages and the automotive industry. In the book, *Death of Competition* Moore considers the relationship between IBM, Microsoft and Intel (Moore 1996). He argues that the success of each is based on their dependency of each other. Even though IBM and Microsoft behave competitively, their success is mutual. Intense rivalry in some markets is in stark contrast to deep co-operation in others. This business ecosystem approach challenges the conventional models that take an industry or market approach. It is the same for business biomimetics, which also has a theme of ecosystem, or at least the interconnectedness of things, at its core. The potential here is to develop a survivability model, bringing together the elements of evolution, information, interconnectivity and environment.

Transformation – the struggle for existence

In a stable world the standard conditions of the past still apply (de Bono 1999). This is not the case for a dynamically changing business environment. However, businesses often behave as if it were. Forecasting and budgets are good examples of where the future is assumed to behave similarly to the past. The business biomimetic approach introduces the concepts of survival and as it is non-confrontational, it encourages all those present to participate so that they can break out of this paradigm. This step

change in thinking built on a gentle non-threatening approach engages a diverse audience of people which is important as the more people involved in a positive way, the greater the positive energy levels. This underpins the idea that businesses could be use biomimetics as the basis for a survivability approach and would further support the argument that being fit for the future is biological. This bridges the fundamental need for every business; reduce costs and grow.

“that natural selection is continually trying to economise in every part of the organisation. If under changed conditions of life a structure before useful becomes less useful, any diminution, however slight, in its development, will be seized upon by natural selection, for it will profit the individual not to have its nutriment wasted in building up a useless structure” p 114 (Darwin 1859)

This could be simply translated to become the mission statement (Campbell and Yeung 2004) of a business. Here is an example of how it could be applied to Thoughtcrew:-

Thoughtcrew is continually trying to economise in every part of the organisation. We will constantly adapt our organisation to the changing demands of the environment by seizing on new developments that make us more successful as they emerge. We will not invest or continue to invest in any non-value adding activity. At the same time, we will grow vigorously focusing only on the present and the changing environment

The ease at which the translation between the observations by Darwin of nature into a useful tool for business further emphasises the appeal of the biomimetic approach: The transformation of businesses to make them more aligned to the environmental conditions and therefore the profit opportunity is a significant imperative. The proven approaches taken by nature tackling similar problems of survival provides the context in which this thesis developed.

The future of the business biomimetic models

Creating models of the future

It could be argued that business biomimetics is a sub-set of complexity theory (Anderson 1999). It may have a role in defining biological research in the future. There could be two approaches to the research which would be how can our understanding of biological systems help us run our lives and defining the problem then look for the biological systems that might help use answer the question. New

research would need to be commissioned, probably funded by business, which may skew the biology research agenda in the future in favour of survival: survival of the cheapest. This would bring together the elements of survival with growth, fitness for the future and the interconnectedness discussed in the previous section. Based on the work done so far there are opportunities for the wider application of business biomimetics.

Areas of biology that merit further research include migration, swarming and seeds. The Flocking model could be used as the basis of examining and defining rules for working as a group. A further detailed analysis of bees and their behaviour is also likely to provide concepts that could be used to develop other business biomimetic frameworks based on swarming, information gathering, team management, leadership and the role of specialists. Seeds provide an expansion on the Alternation of Generation model by potentially adding insight to information storage, distribution and packaging challenges.

Development of the Infinity Process Model into a full consulting method will provide the platform for the application of business biomimetics into the mainstream business market. This is particularly important, as it will develop a clear link between the models and the application in a commercial context. This integrated approach will help business biomimetics become a way of doing business rather than just a set of standalone tools. It also introduces a new way of thinking into the traditional business management model 'market'. Most models are developed in isolation either to refute an earlier approach or a development of the thinking into new areas.

Because of the history of biomimetics the challenge comes from making the distinction between what is a theoretical idea and what has actually been done. An example of this is the creation of a bullet train design based on the beak of a kingfisher. A plausible idea that has not been done yet. (Frank 2008). Without a practical grounding in the development of models that works there is a danger that this leads to an increase in the expectation of biomimetics which is decoupled from the actual experience in terms of results.

Other opportunities to apply this approach include the integration of business biomimetics into TRIZ as discussed earlier. Another way would be presenting the model as a framework in a similar way to the widely accepted European Foundation for Quality Management process. The role is to create excellence in performance,

customers, people and society. (EFQM 1999 - 2003). The EFQM model's role is to provide a best practice framework for businesses and then to benchmark each business against similar businesses. The value of the framework comes from its process and structure, which is greatly enhanced by the business comparison data. The building of such a biomimetic approach would require significant investment. There is currently (March 2010) an opportunity to secure EU funding to build a business biomimetic framework using the Infinity process and the current models. This would provide the infrastructure to further develop the approach and to greatly increase the number of organisations that are taking this approach.

In developing the framework approach, there are two opportunities for model development. The first is to explore the in-depth biology to see if the models work on a number of layers. As discussed earlier, the Past Casting model provides insight in growth, recycling and change management. Other less well-developed models such as the flocking model could be expanded into much more than the creation of business rules. This would potentially generate a way of thinking about the future development of models that builds on the infinity process model

To initiate the application of this approach a core set of questions is needed.

- What are the business problems?
- What will the business issues in the future?
- What biological systems do I know?
- What biological systems could I find?
- What biological systems have yet to be defined?

By asking these questions, it is possible to build a matrix that identifies the gap in knowledge on the one hand and the opportunity for development on the other. A number of attempts have been done to create a database of biology. Examples include the Catalogue of Life and the Encyclopaedia of Life. The latest addition is www.asknature.com by the Biomimicry Institute in the USA who has catalogued over 1500 species by their functional attributes. They are hoping that this approach will make the link to the requirements of engineers easier.

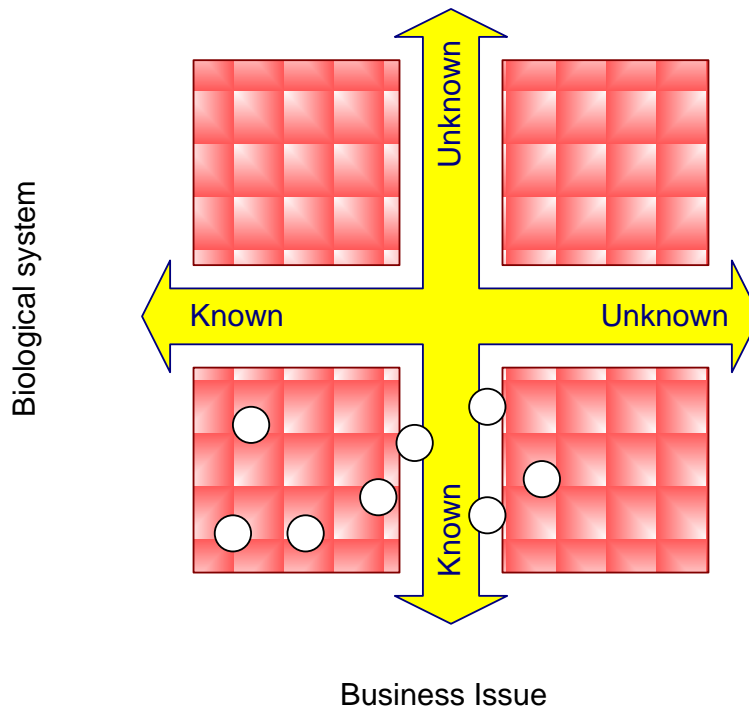


Figure 33: The opportunity to further apply business biomimetics. The circles represent known approaches highlighting the opportunities

This analysis for the existing models as shown in Figure 33 demonstrates that there is potential to explore the biological systems in more detail. The circles on that chart represent the models identified in this research. I have attempted to plot them based on the biological system and the business application. There is also an opportunity to gain a better understanding of the business issues. More importantly, it highlights the significant opportunity to address a wider range of known and unknown business issues. It becomes a significant factor when the range of unknown biological systems is added. It seems pertinent to define the scope based on the needs of business. By taking this approach, it is possible to begin to identify the future work for each model which is shown in Table 35

Model	Future work
Past Casting	Develop a deeper understanding of the biochemistry. Expand this to include other species that moult and identify any useful differences.
Poison Adaptor	Broaden the range of examples and explore the symbiotic relationships to see if this model can be integrated into the symbiosis models to provide a pathway from relationships to implementation
Symbiosis	Explore the various types of symbiosis in more detail. Look at the transient nature of some symbiotic relationships
MRS GREN	Expand this to include other checklists such as the list from Biomimicry (Benyus 1997) or define a new version which would potentially contradict this – not everything needs sunlight for example
Two hosted parasites	Expand this to include multiple species hosts. Develop the lifecycle ideas and get a deeper understanding of vector ¹⁵ transfer
Alternation of generations	Gain a deeper understanding of the gamete stages so that the roles can be explored.
Life stages in two environments	Which other biological systems use this approach? Some thoughts include barnacles that start out as free-swimming organisms and then settle on a fixed spot. This could be a great way to map new start-up businesses to a pathway of development and survival
Flocks, schools, shoals, swarms and	Examine the detailed differences between flocks and swarms. Is there more to the

¹⁵ The biological meaning of vector is used meaning carrier

rules	chorus line effect. Why do some birds flock and others not? Explore the defence nature of this behaviour
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Table 35: Future work for the business biomimetic models

Further case studies, discussed below, demonstrate the benefits of business biomimetics. This subsequent use of the models further substantiates the earlier results which provide evidence towards a conclusion that business biomimetics adds value for businesses.

The application of business biomimetics to business; new cases

This research has been presented to a number of organisations and whilst they are outside the set of businesses examined in the case studies, their responses to the work is relevant and provides another source of input into the discussions when considering the future of the research. I have included examples of how the work is progressing. In the following case studies, a range of business biomimetic models were used. The detail of the approach is not included here as the method was the same as used in the earlier case studies.

Consumer packaged goods

This global consumer packaged goods business is passionate about innovation, design and customer satisfaction. They have a track record in involving leading edge thinking and are keen to explore ways in which they can develop the value of the products they offer. Initially the scope of the work was to explore ways in which the general application of biomimetics could be used to help their research and development operations in the UK. They were given an initial introduction and education on biomimetics then shown a number of examples of how biomimetics had been applied to product development. Following this, the business biomimetics approach was introduced and specifically the Past Casting and Poison Adaptor models were presented to the research and development team. Following subsequent discussions and analysis, they identified three opportunities to apply business biomimetics within their organisation.

- Help Human Resources to manage the integration of a business following an acquisition
- Be used as the basis of their packaging innovation process
- Be used to revitalise their innovation process to help them get out of the perceived rut of similar ideas

All of these ideas were validated using an agreed set of criteria which was based on the criteria used in the earlier case studies. Initially the intention of this work was to look at product functionality but what emerged was the wider business use of the results. The audience was a mixture of research and development people with a number of senior managers. This case provides further evidence that the approach can be used with a wide range of people. Even though the team were initially focused on an engineering based outcome they concluded that the approach could be applied to their business management and innovation challenges.

MoD Procurement

A specialist team responsible for managing the major change programmes within the procurement division of the Ministry of Defence were looking for a way to re-energize. Many had been working on major business transformation programmes for over three years and were scheduled to continue for at least a further two. They were concerned that they were becoming stale and that they were adopting the behaviours of the people they were trying to change. This situation was further compounded by the wide geographic spread of the team. They set out two business challenges, how can biomimetics help us re-energize our thinking and how can it be used as a framework to help us build a high performing team, when we are not co-located?

A workshop on business biomimetics was run at the Royal Victoria Park Botanical Gardens in Bath and the participants were enthusiastic with the idea of using biomimetics, business and the gardens in the same context. The decision by the management team was to learn about biomimetics and then apply the business biomimetic models to the challenge of working remotely. By doing this, the team would be actively learning the new approach through the application to a real business issue. Following an introductory briefing to biomimetics the team worked on developing the true problem definition

Initially the group developed a number of ideas that they believed would address their problem based only on their tacit knowledge, skill and experience. This baseline of ideas was used to set the starting point. A number of key success factors were identified around areas such as employee motivation, engagement, knowledge sharing and promotion. They used the Past Casting, Poison Adaptor, Symbiosis and Flocking model to identify a number of ideas that could address the problem which had been defined as the development of a high performing team. Following the evaluation of

the ideas the group concluded by identifying an increase of 80% in the number of implementable ideas relating back to their business.

IT

Led by the Development IT Director this group is responsible for the development of customer facing support systems and consists of technologists and project managers. As with many IS departments they are internal service providers. There was not an agreed strategy for IS so the department had grown to support a number of key customer contracts. Before this project, they had not evaluated their use of resources nor had they aligned their priorities against profitable customer work. Their key business challenge was how to deliver a more cost effective service with the same resources yet drive better customer profitability. To address this challenge they agreed to try the business biomimetics approach.

The project used three models, Past Casting, Flocking and Symbiosis. The symbiosis model was used to identify the relationship the department had with key stakeholders and say whether this was a 'gain', 'null' or 'lose'. The Past Casting to give insight into what was holding back their growth and the Flocking model to define the engagement models to drive the service forward. The results from applying the Symbiosis model are shown in Table 36.

How you as the IT team benefit?				
How the customer benefits		Gain	Null	Lose
	Gain	Internal colleagues in IT IM energy IM Public sector Partners Senior managers External customers Cardiff Team	Partners Other IT	Internal customers My team
	Null			
	Lose			

Table 36: The application of Symbiosis with an IT team

Overall, the team felt that the customer gained from all their activities however there was a split between the three areas for the team itself. Further analysis showed that they were devoting 60% of their resources to achieve 20% of their results. Following the session, they are reviewing this situation and challenging whether they are working in the optimal way. We also discussed nature's way of creating fit for purpose and fit for the future as a design ideal.

They found the past casting model the most difficult to work with particularly when asked to define their successes over the past six months and for a much longer period of time, eight years. This caused a great deal of consternation within the team where the only feedback they usually receive is negative. Once they had persevered and

created the list the mood changed. Charged with a new sense of success they then looked to see how the Flocking model would help them create an environment within which they could offer a better service by setting engagement frameworks and automating some of the communication mechanisms. One of the biggest 'breakthroughs' was the plan to apply technology to help their own 'business'.

They identified activities that they should stop immediately, activities that they needed to start and activities that they needed to stop if they were going to successfully deliver their overall goals. Following the project the IS team was re-organised and the outcomes of the project were implemented. Feedback from the rest of the business was extremely positive.

International IT consultancy

Management consultancies and those that specialise in IT are constantly under pressure to deliver the latest in approaches and in technology. This international IT consultancy is currently considering the use of business biomimetics in its team building and marketing areas. This is hoped that it will become part of their offer for existing and future clients. Working with a cross section of the leadership it was possible to identify a number of possibilities for the future development of their business. Using the MRS GREN model, they identified gaps in their current strategy.

	Team value based on today's performance	Team view based on business objectives	Key strategic areas for 2008/9	Context notes
Movement	41	45		Optimal deployment of resource
Respiration	32	55		Effective use of energy and investment
Sensitivity	30	74	✓	Ability to be in touch with the customer, market, competitor and internal performances
Growth	37	62		Capability to deliver and sustain growth
Reproduction	28	80	✓	Ability to expand the business by creating more high performance people
Excretion	34	62		Clear understanding about what adds value and what drains resources
Nutrition	33	65		An established process for development

Table 37: IT consultancy use MRS GREN to identify strategic gaps

In applying the model, the group were able to identify two key gaps in their current strategy. Using Past Casting, Poison Adaptor, Flocking and the Symbiosis models the group identified a number of strategic initiatives that could be taken forward.

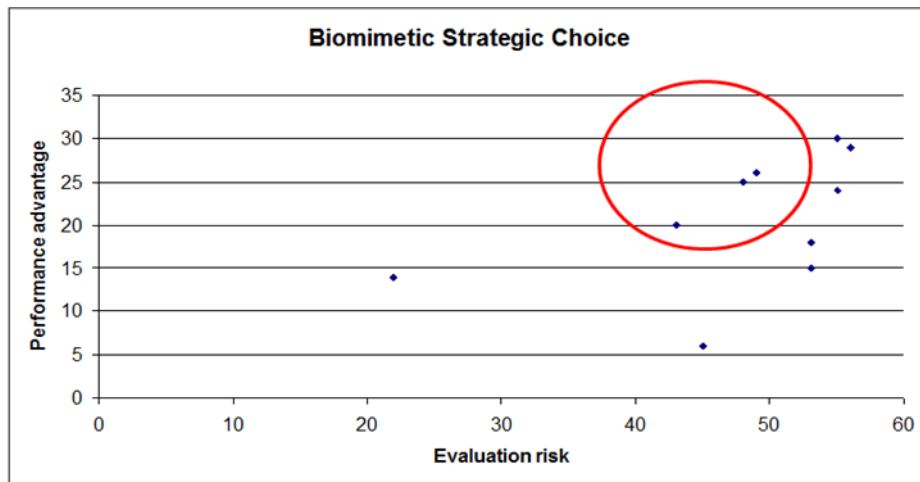


Table 38: IT consultancy use business biomimetic models to identify themes

Note: the initial use of this mapping approach meant that the top left of the chart was the optimal position for an idea. This has since been adapted to reflect better readability for analysis by having the top right as the optimal quadrant.

Based on this approach the themes of role rotation, goal congruence and distinct consulting identity were taken forward by the management team. This provides further evidence of the applicability of the business biomimetic approach.

Summary of the model use

Table 39 shows how the models have been used within the Thesis. This brings together the wide range of applications and industries and indicated the potential for further use.

Model	Test case	Healthcare	Brewer	File Mgt	Military	Weapons supplier	Food & Beverage	FMCG	MoD	IT	Department	IT	Consultanc
Mrs Gren	✓				✓							✓	
Past Casting			✓	✓			✓	✓	✓	✓	✓	✓	
Poison Adaptors		✓				✓	✓	✓	✓				
Alternation of Generations							✓						
Life in Two stages						✓							
Symbiosis	✓	✓							✓	✓	✓	✓	
Two hosts				✓			✓						
Flocking	✓		✓						✓	✓	✓	✓	

Table 39: The total use of business biomimetic models in the PhD

In conclusion, the future of business biomimetics seems bright though with clear challenges. One obvious challenge is engaging with people so that they are prepared to try thinking about and tackling a problem in a different way. Depending on the type of department and the type of industry could make a difference to how motivated people are to consider a different approach to problem solving. The case studies have been taken from a wide cross section so that they can demonstrate the benefits to be gained by using a biomimetic solution.

Chapter 9 Experience with the application of business biomimetics

In this Chapter, the experience gained whilst researching business biomimetics is discussed. Initial conclusions are that this approach is accessible to a much wider range of people than biomimetics: And that there may be a 'top thirteen' themes for business issues. The integration with TRIZ is explored and the way in which business biomimetics can be embedded into the implementation of change.

The application of business biomimetics

Working both as a management consultant and a part-time lecturer with the Open University created a unique environment that allowed me to apply my research as a practitioner whilst having the opportunity to review its application from a number of perspectives. This is important because whilst the PhD work was progressing, in the background I was using the developing material with a range of clients. This allowed me to use this time to develop and apply my thoughts on business biomimetics and what that could mean to business. I was also looking at the commercial opportunity and the future application of the work I was doing.

Based on the examples of further applying the research post completion of the research both reinforced the conclusions from the initial test case and from the case studies taken from industry. They can be summarised as follows. Business biomimetics generates a richer set of implementable strategic ideas and it generates profitable business it has a role to play in Corporate Social Responsibility (CSR). There is evidence to show it helps with build a sustainability strategy. Biomimetics gets cross-functional teams thinking. They become animated, engaged, enthusiastic and energized. Not a typical workshop response. The approach works for charities, government, military, consumer packaged goods, business services, consulting and transport businesses.

The people involved

I have already mentioned the wider range of functions and disciplines involved and believe that as more people become involved, this will accelerate biomimetics from being a technical specialist subject to a much broader business application. An analysis of those involved (Figure 34: audience exposure to biomimetic principles before and after the research

) in the case studies demonstrates this wider audience participation.

Role	Biomimetic literature	Business biomimetic participation
Engineer	✓	✓
Architect	✓	
Finance		✓
Sales		✓
Marketing		✓
General management		✓
Contract management		✓
Academic	✓	✓
Innovation	✓	✓
Product design	✓	✓
HR		✓
Logistics		✓
Procurement		✓
Military		✓
Customer service		✓

Figure 34: audience exposure to biomimetic principles before and after the research

So far, there has not been any audience member that has not participated and enjoyed using the business biomimetic models. Many have volunteered other biological systems as candidates for new models.

The simplicity of complex biological systems

In briefing, a business audience the best balance of introducing biological systems is to use examples that are familiar and accessible. Other less familiar systems can be introduced later after the broad concept of looking and learning from nature is established. Figure 35: A sample of pictures used to introduce biomimetics to a business audience, not all of these models have been examined in this thesis

demonstrates this simplicity and how a single picture can be used to both explain a complex system and as the inspiration to generate new ideas. Each of the pictures shown has been used successfully with a wide range of audiences to explain how business biomimetics can be inspired from familiar objects. This approach also creates an impression and an understanding that the audience can make their own observations in their own environment and attempt to draw out analogies for themselves.





 <p>Kunekune pig</p>	 <p><i>Alcomilla mollis</i> show hydrophobic properties</p>
 <p>'Ghost crab' (<i>Ocypode cordimana</i>)</p>	 <p><i>Bombus</i> sp on Sweet William</p>

Figure 35: A sample of pictures used to introduce biomimetics to a business audience, not all of these models have been examined in this thesis

In the biomimetics community there is much hype about the possibilities of biomimetics yet in many papers the same examples were given; typically Velcro. This particular discovery is over 50 years old and suggests that it is time for biomimetics to move forward. There are a small number of examples where up to date thinking is in evidence. In the US, the Biomimicry Institute (www.biomimicry.org) has developed a database system using biological examples to help product design. Whilst at first sight this appears to offer a 'one-stop-shop' for those wanting to explore the possibilities, nature has to offer, it still experiences the difficulty of translation between complex systems and simple search criteria. It is unlikely that any such codified system will offer a comprehensive answer but it is possible that it will provide some evidence into the origin of biomimetic ideas. The approach still needs to be backed-up by the use of biologists and cannot be used as a stand-alone system. To work at the business level the team needs to have a composite of business and biology expertise. As yet, there does not seem to be a way of codifying the approach for non-expert users. From a commercial consulting point of view, this is where the distinctive competitive advantage can be gained. It is not clear whether the Biomimicry Institute is positioning as a leading academic institution or a commercial enterprise.

Business biomimetics accessibility

The Past Casting model has been the most useful in introducing business biomimetics for companies. It is a readily recognisable biological system and the concept of constraint by success works well. The model provides a way to introduce the concept of biomimetics as an analogy and helps differentiate between biomimetics as an analogy and biomimetics used literally. Once an audience has mastered the overall concept, the introduction of other business biomimetic models is straightforward. The best approach has been to use a combination of photographs of the biological systems accompanied by the model represented as a PowerPoint slide. This ease of access compares favourably with the introduction and education of conventional management models.

Sustainability using biomimetics

One of the challenges in explaining this new approach was how to stop the explanation of the biological system from becoming an interesting education session to becoming a trigger for action. The target market for this education was business people and business leaders in particular. The market in this sense has to be the whole system and not just the technical aspects the evolution of strategy using nature as the guide could lead to strategies that are more environmentally friendly and become a key component of Corporate Social Responsibility and sustainability design. The application of business biomimetics into CSR and sustainability is gathering a great deal of interest. Approaches have already been made to the author by both government and energy companies with a view to building this approach into their portfolio.

The future for business biomimetics

The results from the test case and the case studies combined with the ongoing application of business biomimetics demonstrate that this approach is successful. This suggests that as the work matures and the information and success become more widely accessible that businesses will explore the possibility of using this with their teams. Evidence comes from the increase in demand for business biomimetic workshops.

There is a clear need to integrate the business biomimetics approach with conventional management models to facilitate the uptake of the concept. It is possible that the STEP (Johnson and Scholes 1993) model which is often increased to STEEP actually be extended again to include a biological aspect BSTEEP. Business

biomimetics could be developed as a specific discipline or be amalgamated into the mainstream of management science. Each of the existing established models could be updated to include a biomimetic component. I could see how this could be done for areas such as building a learning organisation (Senge 2007) particularly in the area of systems thinking. These thoughts form the basis of a wider transition of business biomimetics into the mainstream business strategy toolkit. 'The starting point must be driven by the business priorities, the same starting point as the one taken for this thesis. Having identified the start point there needs to be a robust structure to the use and management of information.

The test case results produced thirteen themes and raised the question of whether these themes are predicative for any business problem. Whilst the detailed content may be different depending on the context, perhaps the themes and their descriptions could be used directly as a source of inspiration. Many business books and papers follow a 'top ten' solutions. It would be worth testing this idea with a 'top thirteen' themes (based on the total for group A) paper using the following data as the basis. Note, where the theme is better use of resources this applies to different resources. The themes have been used as per the group results.

Group C	Group A	Group B
become a company	create a centre of excellence	business development
maximum re-use	reorganise and use people differently	core competency
government funding	target marketing	change to project structure
team work	build relationships	operations management
marketing strategy	apply for grants	team work
streamline operations, improve profitability	mass media marketing	innovation
generate revenue	better use of resources	create marketing department
better use of resources	better use of resources	location
better use of people	marketing strategy	management processes
being unique	relationship and image	marketing strategy
	better use of resources	create research strategy
	efficiency and effectiveness	better use of resources
	cost management	better use of resources

Table 40: The 'Top Thirteen' innovation themes

Looking forward to the future, the real value to be found is to use nature to gain insight that will improve our thinking.

What this tells us about creating the business biomimetic models of the future

The limitations of the work done within the thesis revolved around the use of current biological systems as the source of inspiration. These are a snapshot of nature taken in the current environmental conditions. This snapshot does not trace the history or evolution of a particular biological system but it does demonstrate survivability for a sustained period. The ever-changing environmental condition and the relationship between the organisms within it reflect the complexity of the business environment and the changing relationships between firms.

Models such as the Symbiosis model and the Life Stages in Two Environments model explore the relationships between organisms and the environment. On this basis, it could be argued that business biomimetics is a sub-set of complexity theory because of the complex interaction and interrelationship of biological systems. There is an opportunity to also look at the development of technology. What technology evolution might be gained by looking at biological evolution? (Kaplan 2003). It is also possible that business biomimetics will define biological research in the future. There will be two streams of research; what exists in biology that can provide utility and how can our understanding of biological systems help us run our lives. This flips the current situation on its head. Define the problem then look for the biological systems that might help use answer the question. Once our current understanding was exhausted then new research would need to be commissioned. It is my view that this will be funded by business and this will skew the biology research agenda in favour of survival: survival of the cheapest. This has the potential to further blur the role of the University which may become commercially driven. It is likely that this will necessitate a change in leadership and considering the culture experienced during the test case this may be a long cycle of evolution.

Competitors to the business biomimetic approach

Complex adaptive systems have been used to map organisations to the fitness landscapes of a business (Clippinger 1999). The idea is to discover how ‘fit’ the business is for the current and future landscape based on the degree of interconnectedness of the external environment and the interconnectedness of the internal environment. Whilst this could be seen as reflecting the work of Porter for external and Grant for internal (Porter 1985; Grant 2006) it also addresses fit for purpose which is a fundamental design of nature. The ‘fitness landscape’ work

presents a complex approach where the management team needs to “characterise accurately the degree of internal and external complexity of an organisation in order to select the appropriate strategy to achieve sustainable fitness” (Darwin 1859) I cannot believe that this is either a simple process to understand, nor straightforward to implement. Conversely, I have demonstrated on a number of occasions that the Past Casting model can be introduced, trained and start producing results in a short space of time. It is therefore possible to create a ‘fitness landscape’ model, which could be used by businesses to understand their overall context before going on to use the other business biomimetic models.

A number of authors have taken concepts from biology and aligned them to the conventional management approach to developing strategy. Complex Adaptive Systems is a good case where the concept is simple to understand but the implementation of the tools and techniques behind the theory are in themselves complex. Clark suggests that the manager should act as an ‘artificial DNA’ (Clark 1999) where he discusses examples of *Pseudoplasmodium*, where slime mould cells aggregate when food supply is low and then move in a “slug like” manner. He calls this an example of soft assembly, capable of being disassembled as a way of demonstrating a temporary gathering of homogeneous organisms. Clark also indicates that this is relatively easy to create and undo and potentially provides a useful framework for a project based business. This is the closest I have seen to the business biomimetic approach. Many other examples follow the mimicry approach discussed earlier. Feedback from the businesses involved in the case studies tends to highlight the difference between this management and biology approach and the business biomimetic approach as being depth or biology and translation between the biology and business. Management and biology examples are typically fixed models. The business biomimetic approach is a process with a suite of models that can be tailored to the particular business problem. The other ‘close competitor’ to business biomimetics is TRIZ

Determining the appropriate Key Performance Indicators

For the test case to have credibility, I was looking for more than observational data. It would have been possible to gather responses from the participants and measure their perceptions and opinions. Whilst this is a valid approach (Bryman and Bell 2003), I wanted to provide both quantitative and qualitative results. The Research Assessment Exercise (RAE) scores (HERO 2001) provided a useful way of determining a quantitative approach for the research groups. In practice, the composite RAE scores could not be used to measure the actual results as the RAE scores measure implementation and the thesis scope was idea generation. The components of the RAE scoring mechanism, however, did provide the quantitative structure. The score

of 5* (University of Bath 2004) demonstrated that the groups had been selected from the top performing department. What proved to be valuable was the use of the RAE parameters of esteem, journal publications and revenue. These three measures provided both structure for the test case design and as a way of comparing the different groups. The RAE system was overhauled in 2008 (DTI 2003), by then it had fulfilled its purpose in the test case. The measures also translated well into the commercial environment. This broadens up the discussion to the use of information.

TRIZ and complex problem solving

TRIZ principles have previously been explored in a management context (Mann and Domb 1999). An attempt was made to align management principles with the TRIZ principles; suggesting that this could form the basis of a management evaluation framework. The same approach could also be used for the business biomimetic models. To explore this theory I have aligned the characteristics of the MRS GREN model with the TRIZ Principles and presented these results in Table 42. Each characteristic has been assessed against the TRIZ principle and then an index calculated. The index identifies possible relationships between the characteristics and the principles. This approach could be applied in two ways. The first is to identify which principles have a greater propensity to life characteristics and therefore how aligned to a possible biomimetics solution. The second way is to initially use MRS GREN to identify the current situation and the desired situation then to apply the related TRIZ principles to identify areas of solution ideas.

By viewing existing problem solving techniques with this newly created business biomimetic models it is possible to envisage how the technique could be incorporated into existing innovation techniques. The approach adds value to the MRS GREN model and brings in the established TRIZ technique making it accessible to a wider audience. It also means that this alignment of approached is a good candidate for a future research paper. MRS GREN is a powerful model and has been demonstrated as providing a basis for change management, particularly in the initial phases where a comprehensive diagnostic is required.

Evidence of how TRIZ can help solve complex engineering problems is comprehensively documented. An example would be the use of TRIZ to solve the problem of wear on a plough due to friction. The solution involved the use of magnetism which reduced the plough wear, increased the user's satisfaction and produced a measurable increase in crop yield (Xinjun 2003). This example demonstrates that the outcome was not one which could have been developed using existing experience and a traditional approach. Like TRIZ the business biomimetic

approach yields results that are counter intuitive. Many solutions identified are outside the range of the skill, scope and experience of the groups involved and are a way of highlighting the creative effect of using an approach based on research and high levels of evidential data. In another example, TRIZ was used to improve the comfort of bus seats on long journeys. This demonstrated the resolution of the conflicts that existed within the problem. Here the conflict was between the shape of bus seat backs and the shape of the human back. The work used this conflict and the inventive principles to develop and evaluate a number of multi-jointed seat backs designed for a more comfortable journey (Sen 2003)

Contradiction Matrix	Stability of object	Convenience of use	Complexity of device
Area of non-moving object	2, 38	16, 4	-
Stability of object	-	32, 35 , 30	-
Convenience of use	-	-	32, 26 , 12, 17

Table 41: Contradiction matrix for bus seat back design identifying the principles after Sen 2003

Earlier in the setting up of the test case, I looked at the possible relationship between the biomimetic models and TRIZ as both seemed to be looking at complex problem solving. Work carried out (Vincent, Bogatyreva et al. 2005) was starting to link TRIZ to biological models and it seemed that this could also be done for the business biomimetic approach. See Table 42: TRIZ principles & MRS GREN characteristics

A mapping exercise was carried out to see if there was a relationship between the high-level biomimetic models and the TRIZ inventive principles. Table 42 emerged from this exercise.

Principles and characteristics

Principle	Movement	Respiration	Sensitivity	Growth	Reproduction	Excretion	Nutrition	Index
Merging	yes	yes	yes	yes	yes	yes	yes	100
Universality	yes	yes	yes	yes	yes	yes	yes	100
Local quality	yes	yes	yes	yes	yes	yes	yes	100
Segmentation	yes	yes	yes	yes		yes		71.43
'Intermediary'	yes	yes	yes	yes	yes			71.43
Thermal Expansion		yes	yes	yes		yes		57.14
Strong Oxidants ('Boosted Interactions')		yes			yes	yes	yes	57.14
Mechanics Substitution	yes	yes	yes		yes			57.14
Dynamics	yes		yes	yes	yes			57.14
Phase Transitions	yes	yes		yes				42.86
Asymmetry	yes			yes	yes			42.86
Discarding and Recovering					yes	yes	yes	42.86
Porous Materials		yes	yes			yes		42.86
"Blessing in Disguise" or "Turn Lemons into Lemonade"	yes		yes		yes			42.86
Mechanical vibration	yes	yes	yes					42.86
Copying	yes			yes			yes	42.86
'The Other Way Round'	yes						yes	28.57
Another Dimension	yes			yes				28.57
Beforehand Cushioning			yes				yes	28.57
Preliminary Action	yes	yes						28.57

Anti-Weight	yes					yes	28.57
Taking out	yes					yes	28.57
Preliminary Anti-Action			yes			yes	28.57
Cheap Short-Living Objects	yes				yes		28.57
Composite Structures	yes			yes			28.57
Inert Atmosphere			yes			yes	28.57
Parameter Changes			yes			yes	28.57
Pneumatics and Hydraulics	yes		yes				28.57
Self-service		yes	yes				28.57
Skipping	yes		yes				28.57
Flexible Shells and Thin Films	yes		yes				28.57
Equipotentiality			yes				14.29
Feedback	yes						14.29
Periodic Action	yes						14.29
Spheroidality - Curvature	yes						14.29
Continuity of Useful Action	yes						14.29
"Nested Doll"						yes	14.29
Colour Changes			yes				14.29
Homogeneity				yes			14.29
Partial or Excessive Actions	yes						14.29
Total	27	13	21	13	11	12	10

Table 42: TRIZ principles & MRS GREN characteristics. TRIZ Biology, Engineering and Management

There is a bias towards linking TRIZ, biology and engineering in the currently published work. It feels as if this relationship precedent has been set then the work done to make it fit. By creating a database to link biology and engineering functionality (Philips 1998; Vincent and Mann 2002) a classification was logically created from an engineering viewpoint so that everything fitted into a database

structure. This satisfied the argument that nature uses structure and information rather than high level of energy as a principle applied in the design. It should be considered that it might oversimplify the interrelatedness that exists and miss the checks and balances of natural systems.

Change management

Strategy has two components: formulation and implementation (Mintzberg, Quinn et al. 1995). Typically, the implementation is called change management. In implementation, change management impacts on the organisational structure, processes, leadership and technology of a business. Strategic change management (Balogun and Hope Hailey 2008) includes an understanding of the organisation's change context as well as the change requirement, the need to make design choices that are 'best fit' and the transition between the current design and the new design. The context for the organisation plays a critical part and once again, it highlights the importance of the external and internal environments. The change kaleidoscope is a context sensitive model that provides an approach to understanding the organisational change context. It also provides a series of design choices and the process by which to manage the change. It is in this area that business biomimetics excels. It provides the context to manage change without the complexity of models such as the change kaleidoscope. Where business biomimetics differs is in the speed of access and the ability to recall the concept. Both are empirical observations from the test case and the case studies. There are a number of simple models that are also widely used to manage change. Kotter's eight stage model (Kotter and Cohen 2002) provides a basis on which to plan a major initiative. Like many such models it is not clear whether the model was created as a result of observing organisations to create a distillate of ideas or whether it was created conceptually then applied.

Step	Action	New Behaviors ¹⁶
1	Increase urgency	People start telling each other. “Let’s go, we need to change things!”
2	Build the guiding team	A group powerful enough to guide a big change is formed and they start to work well together
3	Get the vision right	The guiding team develops the right vision and strategy for the change effort
4	Communicate for buy-in	People begin to buy into the change and this shows in their behaviour
5	Empower action	More people feel able to act, and do act, on the vision
6	Create short-term wins	Momentum builds as people try to fulfil the vision, while fewer and fewer resist change
7	Don’t let up	People make wave after wave of changes until the vision is fulfilled
8	Make changes stick	New and winning behaviour continues despite the pull of tradition, turnover of change leaders etc

Table 43: The Eight Steps for Successful Large-Scale Change after Kotter 2002

The simplicity of this model highlights two aspects of management. The first is that the models do not need to be complex or complicated. The second is that it is possible to build a significant level of content based on one model. Change involves people and it has been argued that change is only about people (Pettigrew 1988; Cameron and Green 2004). Getting people to change can be traumatic for both the person involved and the manager. What was often thought to be resistance to change is actually competing commitments (Kegan and Lahey 2002) and this brings change into the realm of people, their relationships with each other and perhaps their understanding of self. Such thinking is also related to culture (Munck 2002) and culture change relies on behaviour changes. Change is then closely aligned with people’s behaviour and the need to change that behaviour. It then subtly encroaches

¹⁶ Spelling is from the US model

on the practice of psychology. Change management and its success is then already associated with the biological sciences. This applied thinking is equally important when looking at the stakeholders of a business change. The relationships between the various stakeholders and how they behave can have a significant impact on the degree of success of a change. Stakeholder power and its management is then a critical aspect of change management (Winstanley 1995). This is why the Symbiosis model has such significance in this research. The Symbiosis model works both as a stakeholder diagnostic tool and as a way of understanding relationships and partnership and how they may change over time.

It is important to make sense of change management and how it applies to organisation as a key part of strategy development and implementation. The individual is at the heart of every change (Cameron and Green 2004) and that is why the development and applications of frameworks and models must work at the individual level. This is an important lesson to be carried forward as we look at the application of biology

Reengineering is a key component of change. It can be defined as “the fundamental rethinking and radical redesign of business processes to bring about dramatic improvements in performance” (Hammer 1995). Therefore reengineering is fundamental to the implementation of a step change in business driven by business strategy. Whilst the earlier point of culture was concerned with the behaviour of people, reengineering extends the people involvement to include thinking. The process of managing strategic change, the design of the new business process, and the idea that biology can drive innovation are all linked through the act of thinking. By bringing together the culture aspects through the application of the Symbiosis model and the process aspects of growth through the application of the Past Casting model under a broad umbrella of change strategy defined by the MRS GREN model it is possible to see how business biomimetics can analyse, define and implement change. To achieve change requires the capability of strategic thinking and the ability to encapsulate this thinking in innovation.

Business biomimetics and design and innovation

Challenging people to think differently or reawaken their thinking is a common theme in the innovation literature (Peters 1997; de Bono 1999; Ridderstrale 2000; Marcum, Smith et al. 2002; Peters 2003). A wide range of tools and techniques have been developed to help create this innovative thinking (Van Grundy 1980) where the start point is a problem. Systems thinking (Senge 2007) used to help managers work through complex business problems embraces the cause and effect of systems and

appears to be closely aligned to biological systems. This potentially provides a useful analogy for the application of biomimetics.

Business biomimetics can be seen as the trigger for innovation as well as the source of strategic thinking and when applied to the current situation it becomes the approach to manage implementation.

Innovation in business is about delivering exceptional customer value (Cerasale and Stone 2004). It needs to constantly reinvent the products, services, solutions, processes and even the customers. According to Cerasale and Stone, there is a clear correlation between the creation of new products and an increase in shareholder value. Basing their work on research originally carried out by PriceWaterhouseCoopers, Cerasale and Stone claim that as much as a nine percent increase in shareholder value can be achieved by increasing new products and services by ten percent.

If there is a clear link between research and development and sales growth then there is an opportunity to leverage the process of innovation particularly in the areas of leadership, the creation of a creative environment and the management of ideas (Cerasale and Stone 2004). The formulation of strategic thinking aligns well with the idea that innovation is key to business success

There is a need to design systems, approaches and operational environments that carry out the transformational requirements of a business whilst embracing the innovative aspects, both being essential to the creation of shareholder value. Bettley et al suggest that operations is relentless re-design and this fits well with the idea that R&D is a source of shareholder value (Cerasale and Stone 2004). If customers are driving the operations, agenda and this can be addressed by innovative R&D anything that accelerated innovative R&D will be commercially attractive to businesses.

With such significant gains potentially available, what is the approach industry is taking? What are the key issues of the day and is there any alignment between the opportunity described here and the actual activity being adopted? One place to look for evidence of what is important for business is the consulting industry. This allied profession acts as a business issue barometer selling services that businesses want to buy or convincing businesses to buy ideas and concepts that the consulting industry is selling. Either way the consulting industry is either supporting or creating the top

issues of the day. It provides a useful basis to continue the business biomimetic discussion, specifically when applied to survival.

Consulting

Consulting plays a significant role in business management. Consultancy is applied at all levels of business management from the analysis of the environment, the development of strategy through to the implementation of change and the creation of operational control systems. Change agents follow consulting processes to deliver change (Cockman, Evans et al. 1999). They could be internal managers or external consultants but either way, they play a pivotal role in the management of the change process. As consulting fees are directly linked to what businesses feel needs changing it is assumed that the current consulting activities broadly represent the needs of current business. These fees are usually represented by the 'top sellers' of leading consulting firms. It can therefore be assumed that the topics attracting the lion share of the fees are also the top boardroom issues. The business consulting sector comprises strategy, organisation, project management, change management and human resource consulting.

Consulting therefore provides an insight into the world of business and the potential to use consulting as both a diagnostic indicator of business challenges and then as a mechanism to deliver the biomimetic applications. To get breakthrough in terms of market adoption, consulting would provide a viable channel to market.

Customers

Conventional thinking in both management and marketing says that there is a potent and important impact on customers and employees by the actions of leaders and managers. If, what customers do to each other is more important than what the business does to the customer then survival of a business is reliant on this interaction more than what it does itself. Wikinomics (Tapscott and Williams 2007) is a good example of how this phenomena of interrelatedness is growing. Tapscott et al argue that mass collaboration changes everything. This builds on the discussion about the external and internal environments and demonstrates why understanding components of the environment, customers in this case, is important. It also highlights that the relationship between customers might be more important than the relationship between the business and its customers. This could also hold true for the relationship with the wider stakeholder community

Mass collaboration as a way of biologizing business

My suggestion is to embrace the mass collaboration ideas from Wikinomics (Tapscott and Williams 2007). At this stage, I envisage a simple community of interest (Flocking p 71) who agree to follow a set of rules (Flocking p 71) and to seek government or European Union funding to build the framework wiki.¹⁷ There are many examples in nature where the mass of the crowd is used for reproduction, defence and predation (Krebs and Davies 1993). There is an opportunity to embrace this thinking when putting together the business biomimetic approach. Consider bringing together the wisdom of crowds (Surowiecki 2004), cloud computing (Wikipedia 2010), intelligent data management now used by Google and the information on biological systems and business issues.

This could potentially create a toolset for the use and development of the Infinity Context Free Process and the business biomimetic models. Ideally, it would bring together the biology, management and engineering communities.

Problems with Problem definition

Problem definition was a major obstacle for all of the companies analysed in the case studies. Typically, those people assembled in workshops to participate in group work had a significant amount of company and industry experience. Therefore, when presented with an outline of a problem quickly assigned it to their typical experience and then, without any real evidence or analysis created the possible solutions. This is not an uncommon observation in consulting assignments to note that the group is ready to discuss the range of possible solutions long before the problem has been fully identified. This prejudice or group thinking (Stasser and Stewart 1992) typifies group discussions and often leads to unshared information. The problem is then undefined and as a result inappropriate solutions are developed. This perpetuates a cycle of adjustment and change which leads to frustration and a failure to address the original problem.

This was also an issue for the three groups involved in the test case. Whilst nominally part of a research group, many were unaware of both the work of the rest of the group and the key performance indicators used to measure the group's performance. This is possibly a unconsciously competent organisation (Thompson John 1999) and is created as a result of the values and leadership style of the group's Professor.

¹⁷ Since this chapter was written an opportunity has risen to bid for joint industry and academia EU funding

Despite this lack of congruence between the group's work and the University measures, agreement was quickly reached on the appropriateness of the key performance indicators (KPI's) and their relevance to the workshops. The KPI's were also able to act as the context for the test case thus creating and providing a frame of reference for the research. This way it was possible to mitigate the challenges of problem definition. In applying the approach to the case studies, similar challenges were faced. A critical step was to spend time defining the problem. Not all of the businesses were keen to begin with a problem definition step, as they were often keen to get stuck into the answer. Subsequent workshops have demonstrated the importance of including the problem definition step as without acknowledging what the problem is, it is difficult to come to a good solution.

The challenge, particularly faced when carrying out the case studies, was that businesses did not have a clear understanding of the problems they faced. How can it be possible to improve the situation, when the situation is not fully understood? How can businesses have a seemingly endless supply of answers to a question they have yet to fully define?

Making another chicken

Companies are alive. In the old model companies live, people die: in the new model companies die, people live (Meyer 2003) Looking at this from a business point of view it could be said that a company is an ideal way of making another idea. Just like the chicken is the egg's way of making another chicken! Biology brings a richness of both content and inspiration and this has yet to fully exploited as a teacher for business. It is possible that the application of biology could lead the way to a molecular economy (Woll 2003) which when fully understood may drive very different behaviours. The fact that the most organisms on earth are still bacteria and these haven't been replaced by humans (Kaplan 2003) is perhaps insight into the real order of things and whilst we use phrases like "Save the Planet" what we really mean is save the human race. The planet will save itself. Practically there are a number of interesting angles to explore. Local evolution vs. global evolution – how do organisms optimise for the global environment (Kaplan 2003)? Or do they? Perhaps we should be concentrating on getting it right locally? The coconut crab, *Birgus latro* is the biggest known example of an arthropod and is probably at the limit of how big something with an exoskeleton can be. It can weigh up to 4KG and have a leg span of nearly a metre. Unlike its arthropod relatives, it cannot survive in the water, has a rudimentary lung tissue rather than gills and can manage to drill into coconuts. Clearly adapted to local life in the Indo-pacific islands it is an example of why global may be misleading.

Another way of thinking about how this diversity of life can help us address both the business challenges and perhaps even survival of the species is in the development of life itself. Earlier the research highlighted the real potential MRS GREN has as a diagnostic and planning tool. Another key area in biology is self-copying and self-assembly (Bowyer 2005). It could be argued that this is the basis on which franchising is established. A working model of the business is then replicated, usually with geographic parameters to not only extend the business, but also to build the brand exposure. It provides a link between the topics presented above and a way of approaching the development of business biomimetics. A case of thinking outside the shell.

Chapter 10 Conclusion

Introduction

This chapter draws conclusions from the test case and the case studies. It concludes how the business biomimetic models have had an impact on business strategy and how the management models appear to be best used for short-term revenue generation. Business biomimetics has a clear impact on behaviour in approaching problem solving and idea generation with the corresponding potential impact on organisation culture. The business biomimetic approach provides joined up thinking and the results demonstrate the use both as a toolset and as a process which means that the driver becomes the business issue and not the tool. Business issues are specific to market, industry and organisation. It is therefore possible to contemplate a number of approaches tailored to the specific circumstances of the business problem. This supports a recommendation for a workshop based (Shaw 2006) approach which is a consulting technique that is widely supported by companies such as IBM and Dell.

The possible market for the approach is discussed and a number of suggestions are made for further development and the application of the developed models. The theme of analogy versus mimicry continues and the development of a new process to build future models is presented. A conclusion is drawn to show how the business biomimetic approach creates a relationship between business and biological systems before emphasising the need to maintain an in-depth understanding of biology if the translation between the two is to be successful.

Overall, the chapter concludes that the hypothesis is correct and that when business biomimetics is combined with conventional business models, the new approach can deliver substantial value to business. This chapter will show how the objectives of the thesis have been addressed.

These conclusions were drawn from the test case and the case studies, which were all 'one offs'. This challenges the validity of drawing firm conclusions; however, the patterns that emerged in the application of the business biomimetic models were consistent. This appeared to be valid for both the test case and the case studies. The validity of using the case study method is evaluated in this chapter. Business biomimetics can provide a valuable approach to create tools for problem solving through brainstorming and as a novel process for innovative thinking.

Background theory

Coming back to the original model selection from the Open University model MBA course (see page 18), it could be argued that there are very few new management models that are used in management teaching. Examples of possible weaknesses in the conventional management models have been discussed and whilst the shortcomings are known, the models still provide value in the analysis and development of business strategy

The conventional models have a limited application in a networked service economy. Developed in the industrial manufacturing sector they begin to fail when applied in areas such as not for profit and Non Government Organisations (NGO's). The models are also limited in their ability to manage complexity to changes over time. The adaptation of the Five Forces model to include complementors and to demonstrate the existence of co-opetition is one example (Brandenburger and Nalebuff 1996) where the existing models have been changed with the authors discussing the need to have complementary products and services. This enhanced version is called the Value Net as it allows further value to be added to the industry through complementors (Grant 2008). An example of where this would apply would be the need for printer manufacturers to work with the providers of printer inks, even if they are competitors in one or more markets.

The weaknesses of many management models are that they are used to create a snapshot of a particular situation. The biological systems approach allows a much broader application. Development and change is very much part of nature and this dynamic, networked approach provides a much broader set of application opportunities. As they are inspired by nature, the business biomimetic models create a dynamic model. The conventional management model that assumes that an industry is relatively stable with predictable behaviour ignores innovation. It has been argued (Schumpeter 1934) that competition produces a wave of creative destruction which further highlights the limitation of models such as Five Forces in predicting profitability. The stretch to current thinking presented by business biomimetics is in the element of randomness that natural selection brings (Darwin 1859). Randomness is not typically found as a key tool in strategy development.

Business biomimetics works at both analogy and mimicry. Analogy is used in the sense of 'shared abstraction' after the work of Plato and Aristotle. Shared abstraction is where objects do not necessarily share a feature; it can be an idea, function or attribute. Mimicry or the literal application of biology in engineering, architecture and product design areas was by far the most prevalent approach. I therefore started by looking at biomimetics and its application to business and identified that this needed to be much more analogous than literal. It was getting people to think rather than to copy. The other important aspect in this comparison is that the people involved in the business biomimetics work were not necessarily engineers or architects; they came from across the business world; general managers, sales, marketing, customer service, contract managers, finance, innovation and creative people and planners. Business biomimetics needs to be able to span everything from product design through to leadership development.

Blue Ocean Strategy (Kim and Mauborgne 2005) in making competition irrelevant starts to provide insight into the way a fresh approach to strategic thinking can provide real opportunity for businesses. Blue Ocean Strategy raises the challenge to think about what new industries will exist in the next fifty years. There are parallels in this approach to the changes in the natural environment and a resonance with the thinking behind the business biomimetic approach. Strategic moves described by Kim and Mauborgne are the combination of actions and decisions that pave the way for new products and services to create new markets. This has potential to link to a number of the business biomimetic models. Blue Ocean Strategy is highlighted here as it supports the argument that the traditional models are becoming less useful in the new economy.

Conventional management tools are well established and continue to be used in business today. They are tried, tested and trusted by business leaders. The MBA courses examined show that they are still used in the education of managers. My own strategy teaching experience using these models provides empirical evidence that the models work across a range of industries and sectors. As many of the conventional business models were developed from a manufacturing industry root they do not always work as well in the not for profit, government, military or non government organisations (NGO's). In reviewing the management models applied to the development of strategy, there appeared to be few new approaches, with much of the latest work focusing instead on improvement or adaptation.

There have been a number of attempts to apply biology in business. Most focus on the mimicry aspects such as asking how we can communicate like ants, or manage traffic flows like bees in a hive.

Biomimetics has traction as a discipline with much of the sharing of information taking place between Universities who remain the main focus of expertise particularly on the application of biological systems to engineering and architecture. Germany, UK, USA and the Netherlands are the key countries developing biomimetics to solve product design and engineering challenges. The amount of web-based information on biomimetics has increased in the past twelve months with a greater incidence of blog sites commenting on this approach.

There is a changing need for business leaders to move from cost based thinking to innovation based thinking with a growing demand for tools and techniques to help service based organisations in the development of their business strategies. There is a certain degree of complacency or familiarity with the existing models that mean they no longer stretch the way they perhaps once did twenty-five years earlier. Biology has been used as a management tool. It tends to be used simplistically as a way of getting engagement and this bodes well for its use. Biomimetics is one way in which biology is being actively used by business with a growing community of interest and some early adoption in industry.

The reason for the hypothesis becomes apparent when the three aspects discussed above are considered together. A need for innovative thinking, an acceptance that biology has a role to play and the empirical evidence from a growing use of biomimetics in product design all support the research question.

Focal theory

The original business problem

The business biomimetic approach works for cross-disciplinary business issues. The business biomimetic models were developed based on the current business issues facing organisations. Once applied, the models were assessed for their appropriateness to that specific problem. This is shown in Table 44.

Business Issue	Biological System
Working across functions. Governance.	Flocks, schools and swarms
Supply chain	
Joint ventures, collaborations, competition, co-operation	Symbiosis
Growth and competition	Adapting to toxic environments
Resources and capabilities	Alternative generations
Competition	Parasitism
Growth and sustainable competitive advantage	Ecdysis
Integrated Supply Chain	MRS GREN
Diversification and innovation	Life stages in two environments
Where value comes from in a business, customers	Symbiosis

Table 44: The relationship between business issues and biological systems

In using the models, it became apparent that each model worked best in different situations. Whilst not all the business issues were tested during the test case and subsequent case studies, the business biomimetic models performed as expected. The actual appropriateness can be summarised in Table 45.

Model	Application
Past Casting	Challenging current strategic thinking.
	Growth
Poison Adaptor	Developing competitive advantage
Symbiosis	Analysis of the current stakeholder relationships
MRS GREN	Analysis of the whole business
Two hosted parasites	Developing competitive advantage
Alternation of generations	Long term strategic development
Life stages in two environments	Developing new markets
Flocks, schools, shoals, swarms and rules	Governance, processes, business rules

Table 45: The business biomimetic models and their business application

Business biomimetics brings a new application in the field of business strategy and design. In working with the models under a variety of situations, it emerged that some were better in certain situations than others were. In subsequent application of the models, this distinction has further improved the results. With this limited experience of applying the models, it is possible to identify ‘start points’ or interventions for projects. By defining the high-level problem statement, the appropriate selection of models can be made. This is the approach taken by the Open University Business School in applying strategy models to a business case. It will be

possible in the future to develop a consulting method based on the business biomimetic models in a way that models can be selected based on both the nature of the problem and the lifecycle stage of the project (Weiss 2002). Projects at the initial stage of problem definition and analysis could use the MRS GREN model to help identify the areas for analysis or focus. Projects that have already carried out the problem definition and analysis stage and are looking to carry out a stakeholder mapping activity could use the Symbiosis model.

Business biomimetics generates ideas

The development of business biomimetic models has been shown to develop ideas in both the university group test case and in the case studies. In both, the results show an increase in the number of ideas and in some cases an increase in the richness and strategic nature of the ideas. Whilst the results do not support the hypothesis that business models based on biomimetics can be used as a direct replacement for the conventional strategy models, they show that they can be of great use as an adjunct as they help develop a greater number of implementable ideas. They can also be used as an alternative to the management models and as follow-on to previous use of management models. This means that the business biomimetic approach can be applied irrespective of the experience and use of management models.

When evaluating the three key performance indicators in the test case, the business biomimetic models on their own did not generate as many short-term revenue ideas as the management models. This could be due to the type of business biomimetic model created and possibly, there are other biological systems which have yet to be explored which are more focused to the 'respiration' part of the system. With the small group size, individual differences matter so it is possible that, in the test case, the lower number of revenue ideas for Group A was affected by the lack of commercial experience. The business biomimetic models produced a stronger result for esteem and this supports the link to long-term survival.

The approach taken to identify the business issues as a basis for identifying suitable biological systems appears to be successful. When combined with the observations taken by the application of biological systems to business problems, this supports the concept of a business biomimetic process and the translation of biology to business. Biomimetics can be applied to management science and in the specific area examined here, that of strategic idea development, biomimetics added measureable value with evidence presented from both the test case and the case studies. Business biomimetics becomes the overall approach for the application of biomimetics as it now

encompasses strategic thinking, change management and the development of engineering solutions (see figure 36).

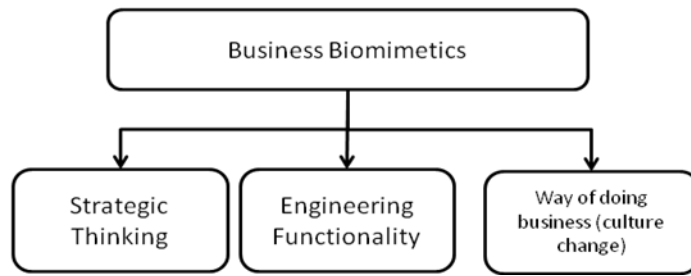


Figure 36: Business biomimetics as strategic tools from thinking to changing culture

The business biomimetic approach is easy to apply. In using, the models across both the test case and the case studies the participants quickly grasped the concept of applying biological systems which suggests that this approach is accessible to a wide range of people.

The biomimetic models are easy to explain. In most cases, it was possible to take a group from first principles to practical application in a very short period. The fast access approach fits well with the expectations of senior managers and this ability to connect with the senior management improves the likelihood of this group connecting with the people they manage. The importance of people in change management is well established (Pettigrew 1988). Selling the idea to senior managers requires a level of accessible functionality as presenting the concept is not enough for operationally based managers.

The biomimetic models are easy to adapt to the style of management. Whilst the research concentrated on strategic thinking aspects for managers, there is still a requirement to demonstrate the practical application of the approach. By developing the models using PowerPoint as the presentation tool, they were available in a very familiar format and this significantly improved the communication of the approach.

The results from both the test case and the case studies clearly demonstrate an increase in the number of strategic ideas generated using the biomimetic models. In the case of the brewery, there was also an increase in the number of ideas over the baseline which could be argued as being the intuitive level for the management team involved. It was also identified that the particular problem faced by the brewery had been tackled on a number of earlier occasions but had failed. The combined

management science and business biomimetic approach not only generated an increase in the number of ideas; it resulted in the problem being solved. The brewery case is a more powerful result in that it demonstrates an effect in a real business condition unlike the test case that was managed within the University and only for idea generation. The approach taken with the brewery would have credibility with other businesses with the test cases providing evidence for the early adoption of business biomimetics by industry.

Depth of Biology understanding

Business biomimetics does not need an existing level of education or experience. The education in business biomimetics opened up the strategic thinking of the businesses involved. There is no educational requirement to grasp the concept other than an appreciation of what nature is. In the development and subsequent testing with the business biomimetic model the need to have a detailed understanding of the biology was essential. Participants were keen to understand the biological system as a way of better understanding the business biomimetic model.

Business biomimetics bridges the gap between the current application of biology in management and the business issues. In contrasting the business biomimetic models developed as part of this PhD with other applications of biology to business there is gap in the detail provided by the existing management inspired biology phrased models (Clippinger 1999).

In many of the discussions with industry the topic of evolution came up as a challenge saying that ‘nature’ had many thousands, if not millions of years to evolve a new species, whereas business typically had to demonstrate results within a quarter (three month period). Darwin demonstrated that man has created new sub species in less than a lifetime (assumed to be 75 years) (Darwin 1859). There is a useful contradiction here. By changing the conversation by adding in the word ‘strategy’ (or its derivative ‘strategic’), the timescale changes. Mergers and acquisitions can take three to five years to create and implement. New product development can take eighteen months and in some industries, such as pharmaceuticals, it can take as long as twelve years and cost as much as \$802 million per drug. (Parloff 2004)

Business biomimetics can be applied in situations where an immediate solution is needed. There is a place for a discussion on evolution in business if we accept that the timescale is somewhere between three months and twelve years. By taking the

variation and selection approach (Darwin 1859), and coupling it with the effect of habitat (Lamarck 1809), an interesting set of factors can be used to develop an evolution biomimetic model. This biomimetic model, once developed, would be a useful adjunct to the capability work of Grant (Grant 2006). With both models a manager looking at the strategy of a business could combine a capability and resources approach with a habitat and selection approach, which would provide a richer set of thinking than the conventional internal and external environment approach (Boojihawon and Segal-Horn 2006).

Business biomimetics is counter-intuitive. In observing the case studies, the most engagement came once the people involved have experienced a counter-intuitive moment. This challenged their existing experience based paradigm and opened up their thinking. Examples included the focus on success in Past casting (as opposed to weaknesses of traditional approaches) and the understanding from the Poison adaptor model that poison could be used as a defensive capability.

Data theory

The use of case studies in social science is an accepted method (Bryman and Bell 2003), however the limitations are recognised with the main critique being the lack of quantitative data. By creating the test case with coupled group workshops with surveys and observation, a degree of qualitative analysis has been completed. The test cases also provided a range of data gathering opportunities from observations, group workshops and surveys and, in the case of the brewery, the analysis of the results. It could be argued that the small number of groups examined limited the number of data points in the test case. The data presented in Chapter 5 suggests that the business biomimetic models have an effect on the generation of implementable ideas which in turn satisfy the key performance indicators. The test case data provides quantitative data. It is possible to question whether the test case satisfies research design criteria such as measurement validity, internal validity, ecological validity, reliability and replicability. This could be further debated to include the low number of group participants and perhaps the test case could have been repeated with another set of University research groups providing intra-group comparisons. This was considered and two separate options were identified and planned, one in the School of Sport Medicine and the other in the School of Architecture. A lack of resources both in terms of the availability of the other research groups in the timescale of the thesis and the increasing workload from the case studies meant that a decision was taken not to repeat the test case.

It is believed that the case studies provided the appropriate validation for the experimental design. They provided this in two ways which were as a validation for the test case and as internal and external validity. The case studies were from a range of industries and addressed a range of business issues. The brewery example provided a longitudinal case and the IT case study was an example of a cross-sectional design (Bryman and Bell 2003). When considering the test case, the case studies and the additional case studies together, there is evidence that the hypothesis has been adequately tested. The final point on validating the approach is attributed to Simon who said *“If we are concerned about the imprecision of case studies as research data, we can console ourselves by noting that a man named Darwin was able to write a very persuasive (perhaps even correct) book on the origin of species on the basis of a study of the Galapagos Islands and a few other cases. To the best of my recollection, there are no statistics in Darwin’s book.”* (Simon 1999)

Each case study provides insight into the application of business biomimetics. There are examples such as the IT case study which struggled in part to apply one of the models, Past Casting, due to their internal paradigm of fire fighting. The strength of the case studies comes from the diversity examined.

In designing and developing this thesis I have taken a positivist approach (Wikipedia 2010). My experience in science, particularly biology and business has played a role in the way the thesis has been approached, the models developed and then applied to the business issues. It would have been possible to select a different area of management science. It would also have been possible to use a different method to select the business issues perhaps choosing a single case and identifying the issues they faced. With almost an infinite selection of biological systems available, it would be an axiom to begin to calculate the options available. I believe that taking the issues that the consulting market feel are important and identifying the biological systems that could be helpful is a valid approach.

It could be argued that a number of the cases were examined using an antipositivist (Wikipedia 2010) approach in that the key observations were concerned with value, beliefs, symbols and the norms of the business. It may also be post modernistic in that my experience is based in the western capital markets.

Evaluating the impact of the thesis

The importance of people in business

Whilst using the models, it emerged that not only did the models have different areas of applicability but also that more work was needed to hone the target audience. Empirically the case studies demonstrated a tendency to mimicry if the audience consisted of engineers and scientists. By contrast, those involved in broader strategic roles found the business biomimetics as an analogy much easier to understand and apply. There was an example with the Army where the group polarised into two subgroups and then debated mimicry versus analogy. In all of the sessions where groups experienced the business biomimetic models, the feedback was positive.

In presenting this work, I am using analogy in the broadest sense of the word. Making a connection between two seemingly unrelated things to help understand and see meaning with the aim of generating a radical new understanding of what might be possible. Perhaps a way in which it is possible to conceptualise identity (Bürge and Roos 2001) is to build on the concept to create an identity in the mind of the participants involved in the research which is holistic (like a biological system). In a number of the case studies, two distinct groups emerged. The first group taking a literal lesson from nature, comparing the utility or functionality of biological systems to their own experience: Do I walk like a crab? The other group embraced the analogy, which was my original intent and therefore my bias, thinking about the biological systems of crabs and how they could apply that thinking to their situation. With hindsight, it might have been more revealing if both aspects had been deliberately included from the start. Despite this, the two effects did emerge with the general acceptance that either could work. The later extrapolation of this to the development of the Infinity Model (presented below) suggests that both are required if the problem is to be solved at both the strategic and tactical level: what do I think and what do I do? This is particularly important for operational managers who are typically more interested in “how do I use this?”

Having the analogy at the start provided a useful way of framing the approach and provided context for the thinking. It was also a useful way to distinguish between biomimetics for product design (how do I mimic functionality?) and biomimetics for business (how do I think differently?). It continues to provide a useful way to access the approach and will be used to shape the analysis question and then the consulting model. Based on the work there appears to be a spectrum of the application of biomimetics suggesting that there are opportunities to apply biomimetics across a range of situations.

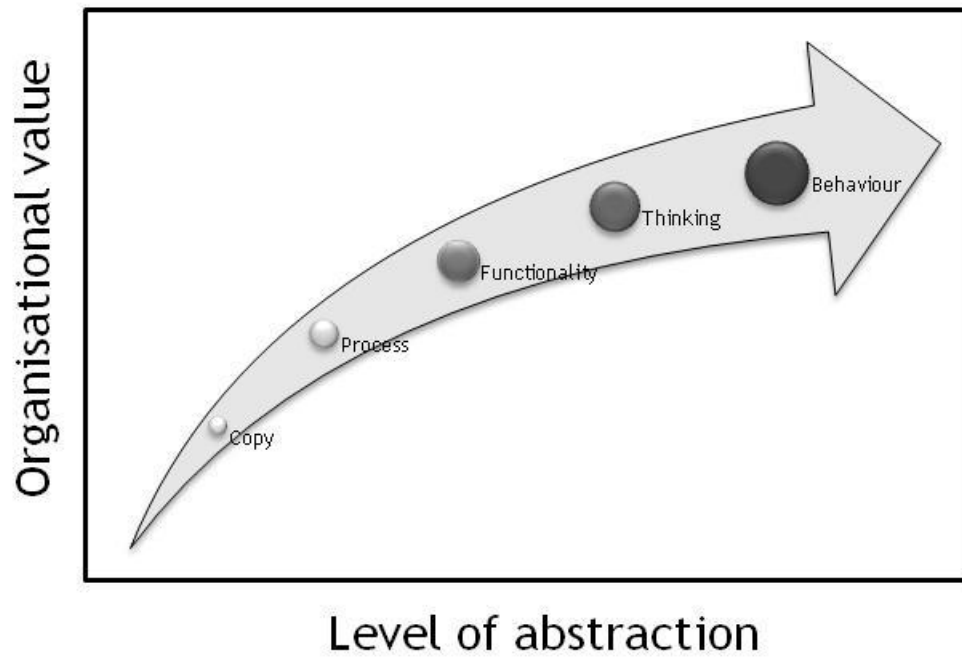


Figure 37: Spectrum of application of biomimetics to show the relationship between value and level of biomimetic abstraction

By determining the business requirement, it would be possible to define the biomimetic approach (Figure 37). The range of biomimetic approaches could then be developed as shown in Table 46.

Level of abstraction	Application
Copying	Most biomimetic applications to date fall into this level where aspects of a biological system have been copied and then fabricated using available materials
Processes	More complex copying often makes use of the underlying processes. The Past Casting model is a good example where the process of ecdysis has been used to help define change
Functionality	This level looks at how a similar result can be obtained by determining how the biological system solved a problem
Thinking	By understanding the biological system it retrains ones thinking to look at problems in a different way extracting the experience of nature and thinking about how best to use this. This level represents a transfer of knowledge from one domain into another.
Behaviours	When the understanding of biology is such that it changes the very approach taken then the final level is reached. Possible applications include the development of environmental strategies and the creation of corporate social responsibility strategies. The ultimate application would be the design and delivery of a culture based on nature for corporate and environment sustainability

Table 46: Different ways of applying biomimetics based on the business need

This ability to adapt the biomimetic process increases the value provided by the business biomimetic approach. A good example of this would be the use of the past casting model to help achieve breakthrough thinking. The biological role of ecdysis provides an excellent structure for managed change. In the crab, the precise regulation of hormone initiated by ecdysone, causes ecdysis to occur and be managed. This is followed by a precisely controlled process involving the shell, muscles, water management and ion exchange. This could be analogous to the change management cycle in business and in particular would be a useful process to use in managing stakeholders (Massey, Montoya-Weiss et al. 2001). In this example the model is applied twice once for strategic thinking and innovation then again for implementation. This usefully bridges strategy and operational managers and improves the likelihood of an idea being implemented. Business biomimetics has provided joined-up thinking connecting strategy to implementation.

Further developing the business biomimetic models

The infinity context-free model (see Chapter 7 Inventing the Infinity Context Free Process) will play a critical role in the development of future models. More work is needed to bring the model to a fully robust solution as not all the variables have been fully tested. Having evolved as a concept from the test case design, the model has

proven to be useful in developing business biomimetic models. Specifically, more work is required to provide a development of the context-free translation part. It is possible that TRIZ could play a role here. With its logical structure and the recent work at the University of Bath (Vincent and Mann 2002) developing a biological database based on the TRIZ principles, this could point to a possible solution. There are limitations to a database approach in translating between complex business and complex biological systems because of the complex taxonomy that would be required. This was the limitation encountered when applying TRIZ to biological systems. A better approach may be to simplify the data onto cards that could be used during innovation brainstorm workshops. Whilst this may be useful as a way of getting to a broad categorisation, it is likely that the expertise of professionals with in-depth business and biological expertise will still be required. Business biomimetics can be incorporated into the current portfolio of management models, the developments in innovation tools and the new online biological databases.

The contribution to strategic thinking

Business biomimetics can make a valuable contribution to strategic analysis and thinking. It is most like systems thinking (Senge 2007) and aligns with complexity theory which has been shown to display common and predictable patterns (Grant 2008). The Flocking model is a complexity model and this is a useful bridge between current models and the new business biomimetic models. Grant suggests that organisations are complex systems underlining the appropriateness of the business biomimetic approach, which aims to simplify complexity for analysis. However, the complexity theory approach does not allow for random creation whereas the business biomimetic approach adds a level of innovation to the theory thus providing a degree of overlap and a way of extending the thinking.

Complex systems are unpredictable, self organised, and they follow evolutionary development which leads to inertia, chaos and small or large changes (Anderson 1999; Grant 2008). Like evolution, chaos theory focuses on fitness. The business biomimetic models provide an opportunity to join with existing management models. Based on the work done so far, it would be possible to add a biomimetic aspect to a number of models such as Five Forces (Porter 1980), Value Chain (Porter 1985) and Resources and Capabilities (Grant 2008). This could be done by providing managers with packages of models depending on the type of analysis being undertaken. One of the key attributes of the infinity context free model is the alignment between the complexity and processes for business and biological systems. Like strategy analysis, this provides a wider context for an integrated analysis and avoids the weaknesses of many management models, as it does not focus on only one aspect. This approach

reinforces the use of business biomimetics as a holistic approach to strategy design and development.

Business biomimetics is counterintuitive to the logic and experience of business management. This is a key observation from the application of nature and suggests that the inclusion of random into the process is potentially the greatest source of inspiration. It raises the fundamental challenge: accepting the current situation, but not looking backwards, how can we apply random changes to the situation to potentially unlock a new business attribute or solution. The business biomimetic models and process would provide the means of facilitating this random input.

Management science

This work demonstrates a new discipline applying biomimetics to business. There appears to be a wide range of potential markets in which to apply the new business biomimetics tools. The test case started by applying the approach to a university faculty and I quickly found that a number of biological models could be applied to their current business situation resulting in a dramatic increase in results.

In doing this work I have also challenged some of the more conventional metrics of managing the performance of a University department and identified during the workshops that most members of a research group are either not aware of, or aligned with, the measures that determine government funding. This clearly is an issue for the University and potentially a useful observation arising from the research. Because of the integrated features of the business biomimetic approach, other aspects surrounding or related to the original problem are also identified. This contrasts to the limited scope of most management models.

Innovation replaces costs as the driver for strategy

The real opportunity for business biomimetics lies with innovation. Innovation is the replacement for cost management as the key driver for strategy development. What this means is that all of those strategy tools and techniques that are cost focused will be significantly less appropriate going forward. Innovation tends to be associated with a quick fix, brainstorming process that generates ideas which are to be considered in the context of the current business problem. Business biomimetics can create a revolution in business because it works for both short term and long term. Not only does it provide the tools needed to generate ideas, it also provides the context within which the strategy can be developed and implemented. The Infinity Context Free

Process provides a way in which to continually develop the innovative approach so delivering the fitness for purpose that is needed. Business biomimetics has a key role in preparing the fitness of businesses for the future. It brings a unique advantage to the portfolio of management tools in that it not only addresses the growth aspects of innovation but also the cost management issues. This was a requirement of management science postulated by Simon in the 1950's when presenting a case for bounded rationality (Simon 1999).

Biomimetic hierarchy

A family of business biomimetic models is developing (Figure 38: Family of business biomimetic models showing MRS GREN as the core model) ranging from broad and general to niche and specific. As new models emerge and the existing ones develop over time, a starting point for the investigative application of the models can be demonstrated. By using, MRS GREN as the core model of life it provides a useful diagnostic start point for the commercial application of the approach.

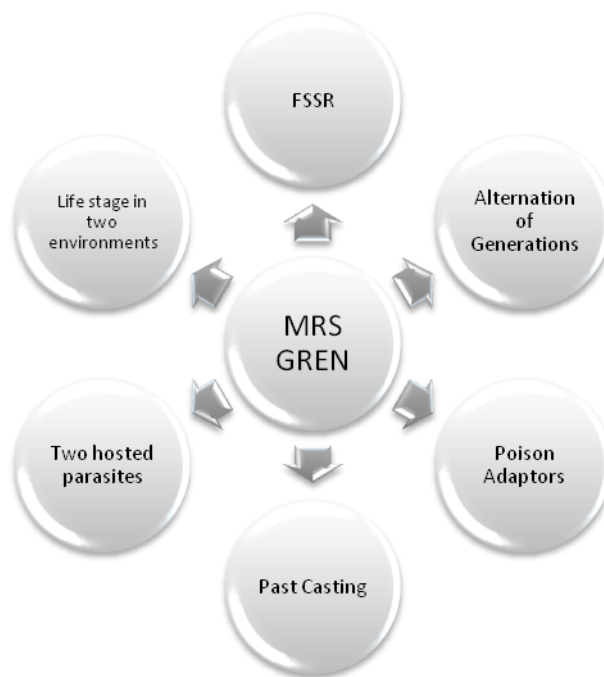


Figure 38: Family of business biomimetic models showing MRS GREN as the core model

Fit for the future

By looking at the resources and capabilities of a business (Grant 2008) and then exploring the resources and capabilities of a biological system, it is possible to identify areas which could be explored in both. This reinforces the fit between the business biomimetic models and the conventional management models. This type of connection is normally difficult to achieve and usually represents the void in

understanding between theoretical models and business practice. Case studies tend to be used to substantiate model claims and are either retrospectively fitted or conclusively extrapolated from observations and application. Biomimetics can generate engagement without the need for case studies or a wealth of rigorous data and quickly engage the user. It is a significant breakthrough in strategy and provides a credible choice for those businesses that accept innovation focus, rather than cost focus, as the way to create fitness for the future.

Biology is accessible to a wide range of people. As business biomimetics, it provides creative output even from those who would not typically describe themselves as creative. The use of biological systems captures people's imagination and can generate a richer set of ideas than the traditional management models. This could possibly be the novel value the new approach brings or the accessibility of nature as a source of inspiration. It can be applied flexibly and because biology is an integrated subject that observes systems, there is an infinite¹⁸ amount of configuration that can be done with the models. There is also an infinite amount of new biology systems to explore and adapt so there will always be somewhere to look for inspiration and potential solutions. Because business biomimetics takes people away from the problem into an area that is more familiar, the approach works to improve motivation, morale and team work. As a leadership development and organisation development approach, it does not have the elitism and educationalist view that possibly some management models potentially have.

Business biomimetics provides either rigid or flexible structure for when teams need to 'brainstorm now'. Rather than rely on their existing paradigms, experience or attitudes the biologically based models guide them specifically through a pathway or provide encouragement to follow a framework. Past Casting is an example of a model that works on these different levels. The constraint that the shell represents challenges people to think about their constraint to personal or business growth. The biochemical pathway of ecdysis pushes the thinking to include the minutiae of detail necessary to manage a change programme.

The infinity context free process provides the core for future model development. Whilst it is envisaged that much of the scanning for inspiration will be based on the business issues, it is possible to start with a biological system and brainstorm how it

¹⁸ Infinite is used in the illustrative sense here as there must be a finite number of biological systems

could be used. This is likely to be the favoured route of those responsible for innovation and searching for what the next ‘big thing’ is.

Limitation of the method used

During Chapter 9, I discussed the limitations to the approach of the method. Individually the test case as an experiment had a low number of data samples (see page 191). The case studies covered a wide range of businesses and looked at different levels of business issue. Individually each could not provide a real test of the hypothesis. However together there was sufficient compelling evidence to prove both the hypothesis and the objectives. This evidence was further supported by the additional case studies shown in Chapter 8.

Meeting the objectives

There were a number of objectives for this thesis. The key objective was to apply biomimetics to business and see if it generated benefit for the business and how significant this benefit could be. The secondary objectives that supported this key objective have been met. Biomimetic models have been developed to address the identified business issues such as working across functions and the need to become customer centric. Traditional management models have been compared with biomimetic models and the ideas produced by biomimetic models have been analysed to demonstrate that biomimetic models could add value for business and stimulate management thinking using biomimetics.

Further work

During Chapters 8 and 9, I explored some of the emerging areas for the further development of the work. There are a number of key areas that I believe are essential to the successful commercialisation of the research.

- Write a book on business biomimetics – this is one of the key ways in which business ideas are shared.
- Present at a number of industry conferences on innovation, growth and change (this has already started)
- Develop a technical solution to allow online access to the process and the models (p 180)
- Apply for EU funding for Thoughtcrew to build the technical solution
- Build on the relationship with Biokon (see Appendix F) to broaden the knowledge across the biomimetic community

- Join a centre of excellence, this is likely to be innovation, design or strategy based
- Continue to develop the range of models
- Write a paper on the top thirteen themes (Table 40)
- Continue to develop the cards (p 145)

Overall, there are a range of actions that can be used to take this work forward. I have already initiated a number of these building on the commercial application of the research discussed in the case studies.

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Appendix A: Test case results, detail

This appendix contains the ideas generated during the initial workshop for each group examined in the test case. The data is shown here to demonstrate the type and range of ideas generated.

Group A (Biomimetic)

Initial workshop ideas

The following ideas were generated by the group. They are presented in the order in which the ideas were entered into the database. This order does not have any test case significance.

Ideas
coffee found big nice table
Alter windows to protect lab equipment
optimisation of sensory environment of office
we need resource, money, equipment, resource (group bank)
everybody in a group has conditions as in prison, no shopping, free home, no destruction (except for torture) that refresh mind
the waste of other departments can be useful for other departments or people
no more than 3 people in the room, loss time on talking
Induction how to use the equipment, what everyone does, projects, safety
Knowledge about how to substitute others jobs. Basic knowledge about patterns of other peoples jobs
technical work, typing, simple tasks, personal secretary
Communal jobs job sheet with stages, sign off stages
To help one another
Rules for the workshop to have a useable workshop
Rules to generate respect, I never do anything that has less than top quality

Associated lack is a job description / geography
Conferences, what I do, what others do, what the world does
Information - all the information in a pack, project list, how to contact us, what could you do
Conferences - define Biomimetics, what does group do? I do best and most important, project
Only do the things you know you can do well, but take some risks?
If I met my MP I could tell them how much I could help them
do not tell tales about other projects, keep criticism in-house, be realistic not rosy
For easy 4-5 scientific publications ask one for the public media/ popular science
Important to know about work of other. Dangerous to go into too many details
Every time I get an offer of money for a project like ours I tell J/W/A/S
I never work on anyone else's project for more than one 1 day a week
Half day a week I have to work on someone else's project
Loss of energy in commuting to office from home
We are wasting time looking for a job if our grant finished, we need personal assistance
Let us buy caravans to live near the University or cheap small flats of better (quick, cheap) transport
Balance between grants duration and money and subject priorities
The speed of implementation of inventions (suggestions, results) should be increased probably like in Japan
funding in science is fashion
fashion in ideas lack of democracy in high level of scientific environment
to utilise social mechanisms (popularity, fashion, traditions, etc) to propagate the things we are busy with
working timetable according to natural rhythm and it should be visible for everyone as poster

look for trendy staff e.g. capitalise on nano tech?
apply for small grants - easier to get, bank on esteem
applying for big grants, takes similar time to get medium grants as big grants
take advantage of transient staff connections - make new collaborations
grow from subdivision - competition between subgroups leads to increased publications and esteem
split the group to foster competition, competition on all levels including esteem, external appearances of the group
expand into new University as collaborations build or post docs move on - learn from them export our structure
projects outside personal sphere e.g. post docs work on a paper together unrelated to their project
involve post docs in the grant writing, named responsible person in group, loan post doc in other groups
identify successful partnerships in this group and copy
Seizing opportunities for talents, interests, experience in the group e.g. sponge co-entry's?
work for others in return for 2nd, 3rd authorship
aim high, max exposure, max citation, impact factor
journal pubs as well as in high impact, maintain a balance
consortium, initial outlay is larger, benefits later outweigh the initial input
take advantage of international connections within the group i.e. group members home affiliations
selecting conferences or workshops with more exposure or return
getting out more - part of advertising
growth by collaboration with other groups
centre of excellence focusing on infrastructure funding
industry conferences as a means of getting people to come to us

buying specialist equipment
getting people to come and use our facilities
abandon teaching particularly undergrad, urgent growth/ recruitment
working teaching share the workload, teaching assistantships
esteem partly a function of teaching reputation

Table 47: Group A initial ideas

Group B (Business)

The results for Group B are presented in the same format and sequence as the results from Group A. Starting with the ideas generated at the initial workshop

Initial workshop ideas

Ideas
teaching courses
experimentally based - become rare
core competency - exploit expertise, inviter testing and teaching
diversity vs. core competency, blue sky ideas or network
IPR protection
improve opportunities to generate and discuss original ideas for projects
innovation evaluation, generation, surgeons, US, exploit and protection
more brainstorming - get out to hospitals - analyse operations
monthly meetings to bring ideas to the table
University of Bath retreat - team building
management retreat
working hours
make most of existing equipment and build links to external
publicise availability of lab equipment for use by external companies - generate

revenue
more integrated lab/office, more projects on machines, more communication between ideas, cross applications, bread and butter testing
list all specialist equipment available in the lab on website so if anyone wants to fast track then hire it = ££
developing links within University and externally
make group structure clearer (streamline)
get admin support (grant applications, salaries, costs)
ensure stuff gets published before you start a new project
maintain independence - integrate credibility
encourage diversity
conduct meetings more professionally
critical mass
minimise number of PJ's output at a higher level
implement quality systems (track and check implementation of ideas (new and old)
task ownership
submit grant applications rather than talk about it
hosting events (industry, academia, media)
publish successful figures (i.e. number of papers in high profile journals)
offer attractive packages to industry
networking contacts - increased publications
seminars (attract high profile speakers and publicise after)
target conferences and take them by storm
public profile - organise charity events
visual identity (house style)
membership to learned societies (active role)

education (public understanding of science) sexy subject (needs exploring)
media profile
identify where to publish and keep to it
identify priorities within funding bodies
be aware of others work (within groups and nationally)
use brains of different people for brainstorming (via email website?)
search for funding bodies (smaller) and avoid vicious circle
website - regularly updated)
dialogue with funding bodies (DTI research councils)
central file space/web space for info sharing (with webmaster)
be more organised (identify key person and let them get on with it!)
identify a person who will keep an eye on funding bodies (charities and companies)
be shrewd (funding & publicity)
strategic thinking!
encourage PG participation in group activities
flaunt it! Facilities, multi-disciplinary
attract researchers (unpaid)
use groups personal and organising skills to offer service to industry
fight 'mechanical engineering' image
money - identify cash cow (niche topic)
be ahead of the game and go for it (Gamble!)
attract new research staff (people = new ideas)
concentrate on niche topic
project our work areas to public (knees hips etc)
exploit links with clinical departments

drink more coffee in less time
exploit expertise in other groups (niche)
rota system between professors/Dr's to do one year teaching and one year research, create marketing/publisher group to help journals
dual edged sword - students & research, change groups to solely focus on research or students, change model to help divide between students and research
people cross working on different projects rather than one, use different people to create ideas e.g. end of PhD people to start new innovative projects
give out aims to groups to motivate, get more cut throat - targets don't meet them you lose! increase productivity - e.g. in summer quiet
geography, being able to be flexible with our customers, could still be University of Bath but based closer - location
utilise technology that doesn't get used in dept and University, materials group, how can help each group
changing culture inside, greater ties with industry, tribalism learn from others
research industrial driven rather than team, combining people to form new groups more willing to co-operate rather than old firmed ones set in their way
increasing communication by group papers, combining/cross group work, utilise resources to open courses on weekends, free people for other projects by changing resources
measuring performance
focus on certain publications, implementation strategy for overall target, keeping tabs on post docs once they leave University to create ties with companies
Head-bangers club
approaching companies, improving income, increased commercial representation

Table 48: Group B initial ideas

Group C (Control)

The results for Group are presented using the same format as those for Group's A and B starting with the ideas from the initial workshop

Initial workshop ideas

Ideas
become a 'centre' (overheads treated more favourably)
personal interaction – meeting customers
spin out as a business
charge extra for over delivering on projects
take on more people briefed with bringing in more business
obtain single vehicle type approval for status emission testing on chassis dynamo
look for more opportunities to patent/licence ideas/inventions
limit number of research leaders (check the criteria)
mergers and acquisitions buy a company or group
provide industrial training courses may need to recruit someone to do this
work faster - do more jobs in a year
hire our post grads as consultants in their area of expertise
hire out facilities for commercial work
put prices up
become and EPSRC shared research facility to attract more income to enhance kit
write more grant applications
interdisciplinary research to access new income streams
attract more postgraduates (with industry links)
applying for more joint research grants with other universities
financial benefit for writing papers (incentive scheme) secretarial support for typesetting and graphical O/P

integrate technical staff with understanding of research being undertaken (group presentations on research)
forefront research
conference in our field
specialized equipment - control hardware - software - high tech
internal research e.g. eamlen engine some other high tech research then go around presenting it
give training courses for professionals (turbo charging workshop)
recruiting wide range of skills to offer a full toolbox
start new research areas to spread our publications subject matter
Link with other universities research expertise to produce joint publications
more internal research (unfunded) for more novel research output
produce more simulation/theoretical papers, requiring less test case load
allow staff time from commercial research to write journals without outside pressure interruptions
collaborate with as many universities as possible on commons. Agree to put everyone's name on all the papers so everyone wins
PVRU open day for industry management engineers
networking with other companies
advertising in engineering field
media coverage TV active
t-shirts and name and fit person smart
web pages
collaborate with local market (specialise)
research projects are proposed with expected publications. Break into test case work (shutdown) to concentrate on papers
specific research staff tasked with journal writing. Supported by test case research

staff producing results
postgraduate associated with commercial work to assist in academic output
Invest profits in funding lots of postgraduate students working on interrelated subjects and get them to write the papers
have a research director, outsource research and development and examining other University trends in research
develop test facility aligned to paper production i.e. one research engine several post grads 15 papers per year
use same core material and write up differently. For target journals, IMECHE, Thermal Power
Write up every piece of commercial work as a journal, however boring the subject matter. Let the referrers refuse papers
produce low grade papers on mass that only just make the journal grade

Table 49: Group C initial ideas

Appendix B: Open University Business Strategy Models

Strategy Management Models	
	Model
	The strategic flexibility paradox
	Standardisation of service
	Potential international advantages of large organisations
	Drivers of globalisation
	The cultural web
	Changing culture
	Organisational culture
	The structuring of organisations
	Successful alliance management
	Alliance development and management, social capital and value creation
	Value creating strategies of diversification
	Ansoff's growth vectors
	Generic testing criteria
	Sharpbenders
	Six types of differentiation strategy and four market characteristics
	Cost based strategies
	Porter's generic strategy typology
	Competitive vs. corporate strategy
	The basic strategic planning process
	Degrees of stakeholder salience
	Salience of stakeholder claim
	Stakeholder power matrix
	Organisational stakeholders
	Stakeholders and their demands
	Porter's value chain
	Evaluating rent earning potential
	Valuable resources
	Linking resources and capabilities
	Resources and capabilities
	The value net model
	Main reasons for coalitions
	Porter's generic strategies
	Competitor analysis

	Identifying key success factors
	Strategic Groups
	The life cycle curve
	Industry structures
	Porter's Five Forces model
	A model of the macro environment
	The external environment
	Strategic issues
	The analytical constructs of the strategy process
	Operational vs. strategic thinking
	Definitions of strategy
	The strategy process

Table 50: Strategy models used by the Open University MBA

Appendix C: Symbiosis future systems for analysis

Host	Partner	Relationship	Relationship
Yucca plant	Yucca moth	Moth grabs pollen and fertilises plant. Moth lays eggs in ovary. Eggs hatch feed on seeds. Not all seeds are eaten these generate other plants. Larva drops to floor pupates and then new non feeding moth repeats cycle	Mutualism
Fire ant	Labauchena daguerri (another ant)	<i>L. daguerri</i> lives in the Fire Ant's nest. Feeds on the regurgitated food. They are 'robber' ants and take food from the worker ants. They can cling onto the host. Lay eggs at the same time and get looked after by the fire ants. Only males and egg laying females - no workers	Parasite
Urechis caupo - worm	small fish, crabs, worms	<i>Urechis</i> acts as an inn-keeper in a u shaped tube. The guests use the tube for protection and their movement draws in food particles for the worm	Commensalism
Man, snail, fish	liver fluke	snail ingests egg, larvae swims into fish, man eats fish	Parasite
British soldier lichen, <i>Cladonia cristatella</i>	green alga, <i>Trebouxia erici</i>	The green alga use their chlorophyll to produce food via photosynthesis. Fungi provides an anchor and a stable environment and also a means of transportation for offspring to move	Mutualism
Convoluta roscoffensis - worm	algae	feeds on small organisms and algae enters when young. Algae uses nitrogen waste from the animal's body and the worm takes on a rich green cells. Eventually worm stops eating and uses up of its algae food supply, which kills both partners. Worm lays eggs before it dies.	Mutualism

<i>Tridacna</i> - bear's paw clam	green algae	green algae stays within a thick purple mantle. Algae able to photosynthesise inside of mantle and provides energy for clam. When clam ages it becomes more dependent on the algae	Mutualism
giant sloth	algae	green colour of algae provides camouflage in the tropical forests. Absence of algae reveals the giant sloth's hair to be yellow. Algae are provided with a place to live	Mutualism
milkweed plant	milkweed butterfly	butterfly lays eggs on milkweed plants. Caterpillar eats plant. When they develop into winged adults and they fly to new territories and the plant recovers.	Parasite
potato beetles	potato	permanent parasites on the plant and devastate them	Parasite
thyme bush	Large blue butterfly, ants	butterfly lays her eggs on bush. Larvae hatch and eat purplish flowers. Ants come and carry larvae away. Ants give larvae shelter in their nests because they can take from them secretions which they turn into honey. Larvae are not harmed and when they emerge as adult butterflies.	Mutualism /parasite
oak apple tree	small fly	insect nibbles the leaf and gives out substance resulting in threadlike fibres growing from the insect. Provides a home for insect as it evolves.	Parasite
sponge	shrimp	shrimp enters sponge as a small, free swimming larva. Shrimp feeds on food organisms that flow through sponge. Eventually shrimp cannot leave as it becomes too large. Occurs in Japan	Commensalism
giant sea anemone	clownfish	Sea anemone kills animals via thousands of sting cells. Sea anemone acts like an electrical fence for the clownfish, protecting it. Clownfish provides large food for the anemone.	Mutualism

sea anemone - <i>Adamsia palliata</i>	hermit crab	young crab finds abandoned snail shell and occupies it. Then hunts for anemone and holds it just below its mouth. Anemone attaches itself there. Crab provides food and locomotion and anemone provides protection.	Mutualism
sharks e.g. tiger sharks	Remora - shark sucker fish	Fin of <i>Remora</i> allows it to attach to a shark. This lets it have protection and transportation as well as access to food of host. This has no side effects upon the shark	Mutualism
Bitterling fish	swan mussel	eggs form in lining of female's shell and then move out into her gills. Tiny mussels become too large to stay in gills and so leave female mussel and attach to Bitterling fish using their teeth. Bitterling fish eggs into female mussels.	Mutualism
Ant	Beetle - the Staphylinids	ants take care of the beetles' young and tolerate the beetle adults eating young ants. Beetles also obtain nourishment by stroking the ants. Beetles secrete a liquid which ants eat. Some beetles also fight with the army ants.	Mutualism
Ants	aphids	ants keep aphids in specially constructed 'sheds' allowing them to move them. Aphids gain protection against predatory insects as well as shelter. Ants also provide passageways to plant roots for food supply. Aphids provide a liquid food for ants.	Mutualism
termites	protozoa	termites cannot digest cellulose. Protozoa in termite's digestive tract which digest cellulose allowing termites to eat the wood. Thus both gain food. Then protozoa dies feeding the termites.	Mutualism
Trypanosma-a protozoa	African antelope	<i>Trypanosma</i> lives in the blood of the antelope and are transferred to humans via tsetse flies. Causes sleeping sickness in humans by producing poison.	Parasite

horse	horse botfly	botfly fastens eggs to hair/skin of host causing irritation. Horse licks spots, ingesting eggs . Eggs attach themselves in pharynx, stomach, or the intestine feeding on blood and leave out of the horse in the waste matter	Parasite
luminescent fish	bacteria	light attracts food towards fish. Bacteria provide the chemicals light. Bacteria gains] food.	Mutualism
crocodile	lapwing	when crocodile opens mouth a bird hops in. Bird performs a dental service of feeding on leeches while croc. Keeps jaw open.	Mutualism
tuatara	petrels	share underground burrows for protection and warmth	Mutualism
Ostrich	Zebra	Ostrich act as scouts and Zebras flush out prey for ostriches.	Mutualism
honey guide	honey badgers	honey guide eats insects such as bees as finds honey. Badger digs out honey and has his fill. Then honey guide eats left over.	Mutualism

Table 51: Examples of symbiotic systems

Appendix D: Definition of ecosystem

This appendix contains the definitions of ecosystems on at <http://www.mywikibiz.com/Ecosystem> as accessed on 20th October 2008 as an example of how one part of biology could be used as a springboard for the development of future models through the infinity process

A community of plants, animals and micro-organisms (biotic) that are linked by energy and nutrient flows and that interact with each other

www.gvrd.bc.ca/operationweb/WQS_glossary.html

The interacting synergism of all living organisms in a particular environment; every plant, insect, aquatic animal, bird, or land species that forms a complex web of interdependency. ...

california.nsc.org/ehc/glossary.html

A community of organisms and the physical environment in which they interact.

www.tigerhomes.org/animal/curriculums/film-vocabulary-pc.cfm

A dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit. ...

sparc.ecology.uga.edu/webdocs/1/glossary.htm

An interacting network of groups of organisms together with their nonliving or physical environment.

www.mwdh2o.com/mwdh2o/pages/yourwater/glossary/glossary01.html

A community of organisms and its physical environment.

www.pewclimate.org/global-warming-basics/full_glossary/glossary.php

an ecological community together with its physical environment, considered as a unit.

www.wef.org/AboutWater/ForThePublic/WaterTerms/

the complex of a community of organisms and its environment functioning as an ecological unit in nature

www.saskschools.ca/curr_content/science9/glossary/index.html

A community of living organisms and the environment in which they live, interacting to form a whole functional system.

www.dnipro-gef.net/first_stage/project-reports/transboundary-diagnostic-analysis-1/transboundary-diagnostic-analysis-of-the-dnipro-river-basin/glossary-of-terms-used-in-the-tda/view

all the living and nonliving things in an environment, including their interactions with each other

www.nhcs.k12.in.us/grade5/science/ch5b.htm

A community of organisms and their interactions with their environment.

www.virtualexplorers.org/ARD/Using/gloss.htm

A complex set of relationships of living organisms functioning as a unit and interacting with their physical environment.

www.adrc.or.jp/publications/terminology/top.htm

Any natural unit or entity including living and non-living parts that interact to produce a stable system through cyclic exchange of materials.

earthobservatory.nasa.gov/Library/glossary.php3

Groupings of various organisms interacting with each other and their environment.

www.alken-murray.com/glossarybug.html

a term used to describe a natural unit that consists of living and non-living parts which interact to form a stable system. The ecosystem idea can be applied at different scales in the same way e.g. a pond or an ocean.

www.sedgwickmuseum.org/education/glossary.html

a system that is made up of a community of animals, plants, and bacteria and its interrelated physical and chemical environment (USFWS).

www.sjrwmnd.com/archydro/glossary.html

A biological system consisting of many organisms that exist in mutual dependence with the other organisms in the system

library.thinkquest.org/22403/data/medium/other/glossary.html

Community of organisms interacting with one another and with the chemical and physical factors making up their environment.

[courses.dsu.edu/eled453/South Dakota Glossary Terms for Science.doc](http://courses.dsu.edu/eled453/South%20Dakota%20Glossary%20Terms%20for%20Science.doc)

a natural unit that includes living and nonliving parts interacting to produce a stable system in which the exchange of materials between the living and nonliving parts follows closed paths; all living things and their environment in an area of any size all linked together by energy and nutrient ...

www.jcpsky.net/departments/environmentaled/blackacre/glossary.html

the entire biotic community plus the abiotic environment

www.users.csbsju.edu/~wlambert/bio115/vocab/vocab1.html

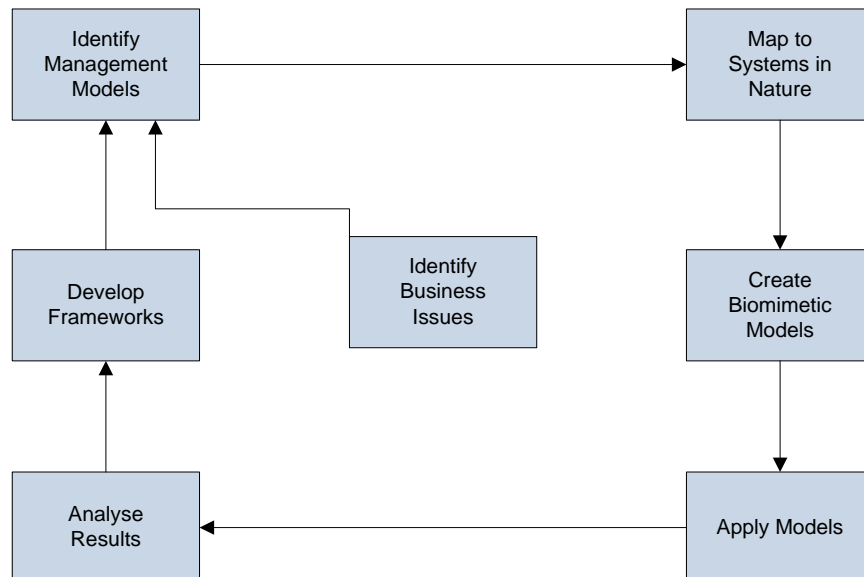
An ecosystem is a natural unit consisting of all plants, animals and micro-organisms (biotic factors) in an area functioning together with all of the non-living physical (abiotic) factors of the environment.

en.wikipedia.org/wiki/Ecosystem

Appendix E: PhD process

PhD process

I have approached the PhD using the following process. Since starting I have also added a step at the start of the process in identifying management models this step now includes looking at the current business issues (as at the end of 2003 start of 2004). I see the full process as cyclical as I am hoping the developed models will become part of the standard tool kit for those involved in the development of strategy.



Appendix F: Technology mission and Biokon

The purpose of technology missions, which are supported by the UK Government, is to fast track technology transfer, enabling knowledge sharing and building relationships and collaborations. My role was to organise the technology mission on biomimetics to the leading edge institutions. There are four centres of excellence for biomimetics, the UK, Germany Netherlands and the USA. During the planning phase, Germany and the Netherlands were the countries that were identified as providing the best mix of university and industry.

In Germany, over 30 million Euros is provided in sponsorship by the Government to an organisation called Biokon to develop biomimetics; this compares very favourably to locally funded projects which take place in the other three countries. Endeavours at the Universities of Bath and Reading have struggled to make real progress commercially possibly due to these funding issues. The University of Reading runs

Bionis, the closest equivalent to Biokon in terms of its mission. This is done on a best endeavours basis with minimal funding through the University. The University of Bath inspired mission was seen as a way of addressing that issue.

The key objectives of the mission were to gain awareness of the current biomimetics research, specifically as applied to commercial exploitation and to explore the way biomimetics can be applied to new product development. Faraday, the coordinating body for the mission, played a key role in bringing together the industry members of the mission and the subsequent dissemination of the mission outputs.

The mission took place in January 2007 with a UK team consisting of designers, packaging experts, consultants and scientists from industry. The team visited a mixture of industry and university locations that includes Philips, Daimler Chrysler, Evologics, Inpro and the Universities at Berlin, Delft, Groningen, Freiburg, Potsdam and the Max Planck Institute. Examples of applications encountered were diverse and included the creation of a laboratory the size of a credit card which was based on cilia, single cell protozoa, *Paramecium*. This laboratory is being developed to carry out diagnostic tests. Thermal insulation has been created based on polar bear fur. Another example looked at the role of superhydrophobicity which means super water repellent which has been analysed in plants to aid the development of self cleaning products.

Commercial applications included the light-weighting of metal structures based on bones, the roof of Stuttgart Airport based on trees, chairs based on the fin ray, underwater remote sensors based on penguins and a steerable endoscope based on the tentacles of a squid.

The mission's recommendations concluded that this was an opportunity for the UK to build on the Biokon example, particularly in Germany and to benefit from the coordinated approach to develop the application of biomimetics. At the time of writing (February 2010) Biokon has launched Biokon International which is now drawing interest from a growing number of countries including the UK. Conversely, Bionis in the UK is still locally funded.

Biokon

Biokon is the Bionics Competence Network and is based in Berlin. It is funded by the German Government and coordinates the key players in biomimetics. They are mainly universities or primary research institutions such as the Max Planck Institute. Its role is to demonstrate the application of biomimetics to industry through coordination, collaboration and education. Biokon is predominantly concerned with the engineering applications of biomimetics. To date the majority of Biokon's activity has been concerned with putting research groups together, acting as a single point of contact for industry and developing the general education on biomimetics.

Biokon International was started in 2009 to address the growing needs of the international biomimetic community. Whilst the UK has yet to initiate a similar approach to Germany, Biokon International already has 85 members from Germany, The Netherlands, Israel, Switzerland, UK and Austria. Collaboration companies include Speedo, Mercedes, 3M, Voss Chemicals, Lotusan, European Space Agency and Continental Tyres. This is an opportunity to expand the engagement of biomimetics as a technique for developing business strategy and a useful platform to broaden the reach of the business biomimetic research.